DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Chemicals in East Germany

LESS well known than the remarkable progress in West German chemical production is the parallel development in the Eastern Zone. During a recent visit to the Leipzig Fair we obtained a copy of the 1956 "Statistiches Jahrbuch der Deutschen Demokratischen Republik". From this and other sources we learnt that this truncated part of Germany holds sixth place in the world for chemical production. Among basic chemicals we might quote a caustic soda output of about 150,000 tons in 1950 which rose to 275,000 tons in 1956; calcined alumina which was not being produced in 1950 is shown with an output of 55,000 tons in 1956. Phosphate fertilisers rose over the same period from 25,000 tons P_2O_5 equivalent to 112,000 tons and organic solvents from 107,000 tons to 214,000 tons. Similar individual figures could be quoted for many other products. On p. 258 we publish notes on the relevant equipment shown at the Fair. Some of the exhibitors were inclined to play down the originality of their wares, claiming the main achievement to be simply the fact of producing so many engineering products in what was formerly the agricultural hinterland of Germany. Whether this be true or not, the expansion is impressive.

Chemicals form by far the largest industry in East Germany. In 1956, out of a total industrial production valued at 47,615 million Eastern Deutschemarks, chemical production accounted for 6967 million; in the process, the industry took 33.1% of all electricity generated in the zone. Most of the chemical output comes from concerns which are described as socialist owned, comprising mainly nationalised and centrally directed enterprises (VEB); a small part of the industry is operated in the form of co-operatives.

In 1957, Britain imported chemicals to the value of £1,297,000 from this source, a small increase over 1956. This represented about half of the imports from East Germany and was additional to smaller amounts of crude fertilisers, crude minerals and petroleum products.

Work Study in the Chemical Industry

AN ounce of case history is worth a ton of theory in discussing work study. On this reckoning the slim pamphlet which forms number three in the series "Notes on Work Study" (published by the Association of British Chemical Manufacturers) must be equivalent to a great weight of unbacked hypothesis. It includes typical examples of the results which can be obtained by the application of Work Study to chemical process work. Costs can be reduced by increased plant output, reduced labour requirements, improved plant utilisation and layout. The principal technique used in the examples described was method study, involving the charting of every activity associated with each process, followed by critical examination of each activity in turn using the questioning technique described in Part II of the B.I.M. publication "Outline of Work Study." In addition, there are cases quoted from the ancillary operations necessarily involved in manufacturing chemical products such as packing and materials handling, and even one on the activities of a market garden associated with one chemical company. Again, in this section, it is the technique of method study which has been predominantly employed. Finally, a section is devoted to the effects of incentive schemes based on work measurement. These cover process work, packing and plant maintenance. The savings effected in these examples range from £200 per year in the case of a small materials handling problem to about £10,000 per year in an application to plant maintenance.

Progress Report on Titanium

WORLD production of titanium rose from 3 tons in 1948 to 25,000 tons in 1957. The story of the research and development behind this phenomenal rate of advance has been recently brought up to date by N. P. INGLIS and M. K. MCQUILLAN*. This survey includes discussion of the extraction and melting of the metal as well as short notes on hot working, cold working and welding. Important properties of titanium are its relatively low specific gravity, its ability to form alloys of very high strength (up to 80 tons/sq. in.) and its considerable corrosion resistance. It also has a fatigue limit which is 50—60% of the ultimate stress—an exceptionally high ratio.

Titanium is resistant to a wider range of corrosive substances than are chromium-nickel austenitic steels. Its superiority to such materials is particularly marked in the case of solutions of chlorides, including sea-water. Even in polluted sea-water, titanium has proved to be unaffected after many thousands of hours under jet-impingement conditions and under conditions which normally give rise to differential aeration effects. Moreover, the corrosion fatigue strength of titanium is actually greater in sea-water than in air; for other corrosion-resistant metals the ratio of the two rarely exceeds 60%. To exploit the metal to its fullest advantage, DR. INGLIS, who is Research Director of I.C.I., suggests that the main objective of future research must be a reduction of costs. Like many other workers recommending new materials he urges specific utilization of the unique combination of properties of the metal instead of using it merely as a substitute for other metals.

* *Endeavour*, 1958, 17, 66, p. 77.

. . . and on Zirconium

More detailed is the summary of metallurgical, physical, chemical and nuclear data on zirconium and its alloys recently presented by C. TYZACK*. This paper includes a compendious data sheet. Strong emphasis is naturally placed on properties relevant to using the metal in nuclear reactors but the scope is far wider including a table of the principal extraction processes. As with many other metals, zirconium is seriously affected by gas contamination in terms of fabrication, physical and mechanical properties and the resistance to corrosion. In general, the pattern of

development since 1948 has largely hinged on the corrosion-resistant properties of iodide zirconium in high-temperature water environments, and the requirement for a sponge-based alloy of equal corrosion resistance for use as fuel component and cladding in pressurized water reactors.

Such a reactor has not yet been developed in the United Kingdom, with its history of gas-cooled reactors with fuel canned in magnesium or aluminium. However, the current interest in this country in the applications of nuclear power to marine propulsion may well stimulate zirconium development. Furthermore, if current British efforts to produce creep-resistant and oxidation-resistant zirconium alloys, suitable for service in carbon dioxide at temperatures around 500°C, are successful, these materials may well have a function as core materials in more advanced gas-cooled reactors. DR. TYZACK is a member of the Research and Development Section of the U.K. Atomic Energy Authority (Industrial Group).

* *Nuclear Engineering*, 1958, 3, 24, p. 102.

Management and Nuclear Energy

EVEN the least technically minded managers now have no excuse for neglecting nuclear energy. O.E.E.C. have recently published the papers* given during the second management information conference on this subject at Amsterdam during last year. Hard on the heels of this important publication came the conference organised by the Federation of British Industries at Harwell along similar lines. Top technical experts and economists lectured to top management on the industrial implication of nuclear developments. Attendance was limited to 100 members of director status including 25 industrialists from overseas. Among the papers were estimates of forward trends in fuel and power requirements and of the consequent financial and investment aspects. J. R. CUTHBERTSON and J. BRODRICK estimated that U.K. exports of nuclear plant exclusive of fuel should rise from a current figure of around £13 million annually to over £60 million in the period 1961-1965, and almost £100 million in the period 1966-1975. In addition, our export sales of radio isotopes, although on a very much smaller scale, are greater in value than those of all other countries in the world combined. W. G. BUSBRIDGE of the A.E.A. (Isotope Division) pointed out that the value of the isotopes is but a small fraction of the savings which can be achieved by their use, and went on to illustrate this thesis with examples drawn from many fields of use. The organisers of the conference feel that growing numbers of firms and industries still only on the fringe of these developments will benefit both as suppliers to the nuclear industry and as consumers of its products and by-products.

* "*Industrial Challenge of Nuclear Energy.*" 1958. O.E.E.C.

Radiation Research Tastes Good

MOST amusing part of the recent meeting held by the Radiation Research Visiting Club at Cambridge was tasting irradiated chicken, sausages and sponge cakes. We hope it was also useful. Comments were carefully noted for the guidance of workers at the Low Temperature Station intensively studying the use of ionising radiations for preserving food. The crowded programme of this busy Club included visits to the University Chemical Laboratory to inspect work on the radiolysis of gases such as oxygen and simpler solids such as sodium bromide and potassium chromate. Thermal annealing of radiation damage is also being studied. Papers were read on germane topics and a further visit arranged to the rapidly expanding research laboratories of Tube Investments at Hinxton. While the current research is concerned with fundamental reaction mechanisms, the whole event left a strong impression of vitality and growth in a field of work which will soon reach the stage of industrial processing. "Growing points" may well be the promotion of polymerisation or processes leading to graft co-polymers or to speeding the chlorination of organic compounds. Further programmes are also in progress at the A.E.R.E. laboratories, Wantage and the Military College of Science, Shrivenham.

Compacting and Sintering Metals

ALTHOUGH a powdered metal differs from dense-solid or liquid metals in having a reaction surface larger by many orders of magnitude, this surface is connected with the surrounding atmosphere for the most part only by very narrow capillaries and in such a manner that inter-action with this atmosphere can take place only by molecular diffusion. Therefore different equilibrium conditions may exist on the inside and outside of the material to be sintered. However, with this structure we have very short diffusion paths from the interior of each grain to the surface, which means that the decrease in the reaction rate caused by diffusion is not very important. At a recent discussion on the practice of compacting and sintering metals, DR. OTTO WINKLER discussed particularly the problems arising from these considerations in carrying out effective vacuum sintering of such metals as nickel, iron, niobium, tantalum and others. The conference, jointly organised by the Iron and Steel Institute and the Institute of Metals, also heard a paper by T. R. BARRETT *et al* on pressureless sintering of loose beryllium powder. This has apparently now been established on a production basis by the Atomic Weapons Research Establishment—recently in the news for other reasons. Loose beryllium powder of bulk density about half the true density can be formed into compacts of 95—98% the true density, that is 1.76—1.81 g./c.c. The complete set of papers has been issued in duplicated format by the two institutions.

Silica Cement Resists Sulphuric Acid

TANTALISING but interesting is a paper on a new silica cement mortar which ROBERT S. MERCER was due to present to the National Association of Corrosion Engineers in California. Instead of using sodium or potassium silicate as a source of silica, the new product derives its silica network from a silica sol. The commercial sols available are of low viscosity and contain 30 to 35% SiO_2 as a colloidal suspension in water. MR. MERCER states that many attempts have been made to use silica sols to prepare mortars and cast shapes, by mixing the sol with siliceous fillers such as are used in the classical silicate mortar. They have failed. Simple mixtures of sol and fillers have poor strengths after the water is removed. Strong acids, alkalies, and electrolytes cause gelation of the silica so that the mass sets rapidly without depending on dehydration, but the solid masses are very weak and can usually be crumbled in the hand. Now a silica gelling agent has been employed, which will provide strong masses, thus permitting mortars to be formulated that have higher strengths than the classical silicate mortars; and more important, without the disadvantages of the silicate mortars in sulphuric acid service.

Since the product is essentially silica, it is described as a silica mortar rather than a silicate mortar. There are no fluorides in the mortar, hence no HF can be formed in sulphuric acid service. The sodium or potassium content is reduced to a maximum of 0.7% expressed as Na_2O, or can be eliminated, depending on the formula-

tion. Therefore, the problem of sulphate and polyvalent alum formation ceases to be a problem.

The mortar contains 98% SiO_2. Compressive strength is reported to have risen from 2190 p.s.i. to 6530 p.s.i. after 56 days immersion at 410°F in 93% sulphuric acid solution containing 1.25% ammonium sulphate and 1.25% sodium and iron sulphates. Equipment test results also showed gains in strength. Then why the opening word? Because neither the filler nor gelling agent compositions are quoted.

Mixer-Settler Design

A RECENT paper by J. K. DAVIDSON and others on design and scaling up of mixer-settlers* puts forward strong evidence to support the view that multi-stage units of this type provide a means of obtaining high efficiency mass transfer with flexibility. As a general rule, the efficiency of mixer-settlers is between 75 and 100%. Each actual stage approximates to a theoretical stage.. Comparisons are made in this paper of various contactors for the system acetic acid—methylisobutyl ketone—water on the basis of effectiveness, defined as the inverse of residence time per stage. The main discussion then centres on a design developed by the Knolls Atomic Power Laboratory called the "Pump-Mix".

This is a horizontal contactor in which the mixing intensity, automatic liquid-liquid interface control, and hydraulic head for heavy-phase flow are provided by the impeller. The need for individual stage interface sensing and control devices, or for tilting the unit to provide hydraulic head, is eliminated. A contactor consists of any desired number of stages arranged horizontally. Each stage contains a mixing section and a settling section. A heavy phase "chimney" between the settling section and the mixing section eliminates the effect on the interface level of a density difference between stages, since the heavy phase in the chimney has the same density as the heavy phase in the settling section. This is particularly important in complex flowsheets where large density differences may exist between extraction and refluxing sections.

Scale-up is generally effected by maintaining the settling zone residence time constant for a given system. The paper deals with the application to the Purex process but the authors point out that this scheme may be used with other processes because there is little difficulty in scale-up. Representative decontamination, partition, and loss data can be obtained from "mini" or laboratory-size banks using ¼ litre of feed per run. Adequate design information on capacity, settling, optimum stirrer speeds, and other factors involving hydraulic behaviour can be obtained from pilot-plant size banks with a total flow capacity of one litre per minute. All such information is applicable to units varying by many orders of magnitude.

* "*Application of Mixer-Settlers to the Purex Process.*" KAPL 1809. Available from Office of Technical Services, U.S.A.

Getting Sense from Babel

MANY are the languages in which useful scientific information is published. How can the working scientist-engineer be helped to understand it? ASLIB recently organised a Conference on Scientific and Technical translation. Among the interesting contributions was one on the all-important subject of costs. MR. FELIX LIEBESNY, Patents Information Officer of Mond Nickel, attempted some estimates for the true total cost of translating a 1000 word article from Russian into English. It could range from 4d. to £6 6s. The lower limit was achieved by using a completely translated journal on the assumption that one article in 40 was of use to the subscriber. Next to this was the probable cost of mechanical translation at about 2s. The limitations of these methods are of course quite evident, yet there is such a large gap between these figures and the normal range of around £3 to £4 for conventional individual translations by a professional translator, that it is clear which way the trend is likely to go. MR. LIEBESNY was naturally careful to add that there are many other factors involved such as speed, accuracy, number of copies required and secrecy. Any of these special needs may make an apparently uneconomical method nevertheless the most desirable.

Other contributors urged more work in establishing national registers of translations and in compiling specialist technical dictionaries covering very narrow fields. A paper by MR. A. L. MACKAY carried echoes of the great controversy about the content of education. The difficulties he suggested arose really from the lack of scientific education among those qualified in the humanities, and the lack of linguistic education among those qualified in science. With a final kick MR. MACKAY observed that although there has been some improvement lately, science means to govern-

Aluminium in Oxygen Plant Construction

We have received a copy of the following informative letter:

March 7, 1958

Mr. M. A. Dubs
Union Carbide & Carbon Corporation
Tonawanda, New York.

Dear Mr. Dubs,

Your article on "Recent Developments in Industrial Oxygen Production" which was summarized in the February issue of *British Chemical Engineering* (p. 94), gives much valuable information but I think there are two paragraphs which might be misunderstood.

It is stated that the aluminium alloy with 3.5% of magnesium is not used under conditions of cyclic loading because the fatigue strength falls off rapidly after about 1000 cycles. The implication is that competing materials do not show this characteristic whereas available data indicate that they do. Perhaps the impression that the effects of cyclic loading are different for the aluminium alloys and ferrous materials was obtained from the fact that data for the aluminum alloys are usually plotted on semi-log coordinates and that for ferrous materials on log-log coordinates. Even the same data plotted on these two coordinate systems might give conflicting impressions.

In connection with welded butt joints, it is stated that "butt welding is seldom successful". Experience in America with inert gas shielded processes has been quite satisfactory. It is true that aluminum alloys require some edge preparation, such as beveling, before welding if the thickness is greater than about 1/8 in. Is this not also the case for competing materials?

Very truly yours,

ALUMINUM COMPANY OF AMERICA

Ellis D. Verink, Jr.
Manager—Chemical Section
Sales Development Division

ments today essentially what it meant when LEONARDO DA VINCI applied for a job with the DUKE OF MILAN. He listed the various military projects which he could carry out and added as an afterthought that he could paint as well as the next man.

The papers will appear in "ASLIB Proceedings."

Quiet Please

DAMAGE to the hearing mechanism that results from noise exposure occurs in the inner ear. The small nerve endings that send electrical impulses to the brain are destroyed by the energy from the noise exposure. The nature of this destruction is apparently identical to the destruction of the nerve endings in the inner ear due to advancing age. This hearing loss is permanent and cannot be restored. A group of the papers presented at the Montreal joint Canadian-U.S. Chemical Engineering Conference discussed several aspects of this problem. To estimate both the auditory effect on employees and the influence of noise on processes and process instrumentation, LEWIS S. GOODFRIEND suggested measuring many or all of the following characteristics of a particular noise: sound-pressure levels in third-, half-, or full-octave bands; instantaneous peak sound-pressure levels, narrow-band spectra and waveform.

Typical causes of noise are vibration, impact, turbulent fluids and friction. GEORGE L. BONVALLET, after discussing these noise-sources in general terms, presented information on the conditions near a refinery catalytic cracking area, steel-ball paint pigment mill, high temperature fabric coating operation, and a plastic dicing machine. Noise conditions have to be considered with respect to the hearing hazard, interference with important factory conversation, and acceptable neighbourhood noise. The data presented at the conference showed the chemical industry not to be a serious offender although there are problems requiring attention. For such cases T. F. W. EMBLETON recommended an approach based on first trying to modify the noise produced. Failing this, the source may be enclosed, the surrounding surfaces made sound absorbent or a sound-proof booth built for the observer. As a last counsel of despair, and quite out of keeping with the high scientific tone of the rest of their discussion, this author even recommended ear plugs.

No Smoke Without Powder

SMOKE is among the terms objectively defined in the useful new British Standard (No. 2955:1958) giving a glossary of terms relating to powders. According to this the visible cloud of airborne particles derived from combustion or from other chemical reaction is smoke when the particles are mainly smaller than 1 micron. Fumes are defined as clouds of airborne particles, generally visible, arising from condensation of vapours or from chemical reaction. The boundary for separating grit from dust is taken as 200 mesh B.S. test sieve which has an aperture of 76 microns. The glossary covers a number of selected terms applying to both metallic and non-metallic powders. An arbitrary decision has been taken—as the foreword points out—by restricting the definition of a powder; the particles of which it is composed must have a maximum dimension of less than 1000 microns in any direction. However, an agreed decision backed by the wide range of cooperating organisations which supervised the preparation of this Standard, is likely to gain wide and unified acceptance; it is thus technically valuable even if it is arbitrary. The compilers have recognised that in certain industries particles larger than 1000 microns may be classified as powders but it is hoped that in due course the foregoing limitation will be accepted.

To follow the direct glossary of terms there are two appendices. The first goes into some detail on the definition of particle mean sizes while the second shorter one gives an example of calculation of diameter according to Stokes's law, defined in the same Standard as Stokes's diameter.

Air Filter Arrangements for BEPO Wigner Release

FOR the recent Wigner release operation on BEPO the atomic energy authorities announced that special precautions were to be taken to prevent any escape of radioactivity into the atmosphere in the event of an accident in the pile. We have now been informed that the following filter arrangements were adopted. A bank of twenty-eight frames were arranged in zig-zag formation across the duct. Each frame contained six layers of filter material consisting of starch-bonded glass fibre oiled with Shell oil, Tellus 72. This is an oil of exceptional chemical stability of viscosity equal to an SAE 90 gear oil. The frames were sealed in position by felt pads. For particles between 10—15 microns the filter efficiency was about 90%. These were backed by 168 Vokes high temperature Kompak filters aranged across the duct and having an efficiency of 93% for particles below 10 microns. Finally the air was passed through Vokes 55/5 "absolute" air filters. These were tested by the methylene blue test in accordance with B.S. 2831: 1957. The results are quoted as percentage penetration rather than as arresting efficiency, since the former figure is more informative at these high efficiency levels. On this basis the filter efficiency was 0.01% penetration of methylene blue, that is for an average particle size of about half a micron. Similar filters were placed in a further iodine scrubber device which was by-passed during the operation. This additional set of filters was intended to be available in case of an emergency.

Plastics for Packing Chemicals

IN an issue largely devoted to packaging problems, *Kunststoff** includes a short survey of the use of plastics for this purpose in the chemical industry. ERNST RAMSPECK points out that all polyamides produce film which is resistant to tearing. For example, those on a caprolactam basis are chemically stable and suitable for sacks and bags, particularly for containing sharp-edged granules. They may also be used as lining sacks for metal drums. Since they are stable up to 120°C, products may be packed warm, directly from a process, which can be an advantage in certain cases. The packings may be made as a double bonded film with polyethylene to give lower permeability to water vapour thus making a suitable container for hygroscopic materials.

There are several possibilities for replacing glass as a material for small and medium size containers. Acrylonitrile — butadiene — styrene mixed copolymers for example have high impact strength and are resistant to alkalies, dilute acids and benzene but they are opaque. Paper sacks can be made rain-proof by melamine resins or other high molecular weight products. The process is simple, it simplifies storage and the surface is easily printed. A final practical suggestion is that when handling sticky materials a layer of silicone rubber can often be usefully applied inside paper wrappings to resist this property. A satisfactory effect is produced with layers of 5 g. per sq. m.

* *Kunststoffe*, 1958, 48, part 2, p. 65.

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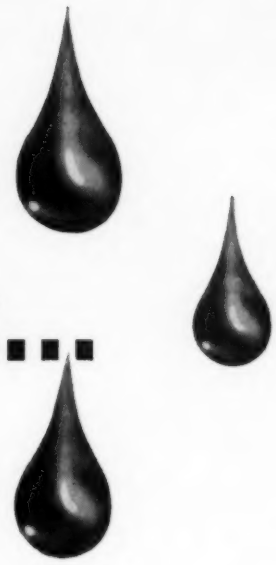

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British Chemical Engineering
A HEYWOOD PUBLICATION

Shortage or Surplus?

IT is often the case that the magnitude and urgency of a social problem is measured by the volume of attention it receives from the professional bodies; with higher education this is especially so, since within recent months most of the major engineering institutions of this country have made some pronouncement on this subject as it relates to their own sphere of interest. From the Institution of Chemical Engineers comes the latest contribution to this ever-recurring topic, with a report of answers to a questionnaire sent to technical colleges and universities. This questionnaire sought to discover the probable output of chemical engineers over the next eight years or so; in the summary report of the replies to the questionnaire, it is concluded that with adequate support (and this is an important qualifying clause) it would be possible to provide nearly 950 chemical engineers in 1966 compared with the 300 or so who emerged in 1956.

How does this prediction measure up against the estimate of engineers required? Actually for 1966 a number of figures have been given, varying from 1000 to 1500 a year. The Institution, in its statement, appears to favour a figure of 1100 apparently derived from a recent report, "Scientific and Engineering Manpower in Britain". This number of chemical engineers is consistent with a forecast of engineers and scientists in the next 10 to 15 years of double the present actual output. Here it has to be appreciated that the rate of increase in investment in chemical and processing undertakings (7 to 8%) is about double that for the remainder of industry. The Institution's estimate of the supply of chemical engineers is, therefore, close to the estimated demand. It is pointed out, however, that in 1959 there is likely to be a surplus of chemical engineers. If a more detailed examination confirms that this situation is likely to arise, then something should be done to deal with the problem in good time.

On the other hand, by 1966 the figures show that supply will not quite match demand, although a proviso, as we have noted, has been added that adequate support must be given to the centres of engineering education. The outstanding problem affecting the output, both qualitatively and quantitatively, is the supply of teachers. Professor after professor will complain of the near-impossibility of obtaining the staff he requires. At some universities, so difficult is the position that staff are perforce recruited from among the "brighter" graduates, men who may possess excellent theoretical knowledge but have little practical experience. This, of course, affects the product of the college and leads to an engineer with an unevenness of outlook which may take many years to eliminate.

Although there are heartening reports of steps taken to expand technical education—300 projects to the value of £60 million are under way and grants to students are to be increased—the position of education generally is a far from healthy one. The financial measures taken to encourage investment in this country have already left their mark on the earlier stages of education. All local authorities, for example, have been forced to reduce educational expenditure by considerable amounts; as a whole, expenditure in 1958/9 is to be reduced to £11.2 million spread over 15 months compared with £14 million in 1957/8. More than 30 secondary modern schools had to be cut from the building programmes for rural districts last year. Although the Government may claim credit for increasing the amount devoted to education during 1957 by £26 million, we should remind ourselves that this is the smallest increase for a number of years. Furthermore, today the nation devotes a smaller proportion of its annual expenditure to education than it did 20 years ago. It is estimated that to implement the Education Act something like £1000 million needs to be spent annually and a further 50,000 teachers are still required. Since expansion of technical and higher education depends ultimately upon thriving primary and secondary stages of education, the various estimates which have appeared for the future output of technicians border on the optimistic.

To be able to bring about such a startling increase in the production of chemical engineers as the report envisages at a time when the general educational climate is far from temperate, and in the face of an acute teacher shortage, will be no mean achievement. If the figures forecasted are only approximately reached, it will mean that the leaders of chemical engineering education will have succeeded in insulating their particular branch of education from the adversities which other branches of engineering education have been unable to escape, and whatever is obtained over the years ahead, it will have been carried through with limited official support. It is possible that the financial measures introduced—on doubtful premises—to check inflation may yet have such a retarding effect upon industry that the expected surplus of chemical engineers which the summary states will exist in 1959, may assume much larger proportions through a reduced intake of engineers by industry. Are the numbers who make up this surplus to seek temporary employment in fields of lesser status and skill and thereby lose the force of their special training? Were this to happen, not only would useful technical potential be wasted, but sixth formers and others would be discouraged from taking chemical engineering courses. This factor alone might well place in jeopardy the increase in engineers which the Institution thinks possible and appears to accept as a target.

The logical thing to do, in view of the teacher shortage, is to seek redistribution of chemical engineers to the advantage of the teaching side. By some mechanism or other, a demand for chemical engineers must be created additional to the normal one made by industry. If industry can be persuaded to release permanently some of its experienced chemical engineers for teaching in universities and technical colleges, and if conditions in these establishments could be made sufficiently encouraging to justify such a move, then the educational position might be strengthened.

66.096.5: 621.317.39

POROSITY MEASUREMENTS IN A FLUIDISED BED

A new method of porosity measurement described by the authors has demonstrated the existence of three distinct regimes within a fluidised bed. The paper also includes reviews of other work in this sphere

by P. J. BAKKER and P. M. HEERTJES

THE extensive development of fluidisation technique in recent decades and, parallel with it, of research on the physical and chemical aspects of fluidisation were strongly stimulated by the great demand for high-octane fuels during the Second World War.[1] After the petroleum industry many other industries also became interested in the fluidisation technique (see BROTZ,[2] SITTIG[3] and OTHMER[4]). It is of historical interest to note that in 1556 AGRICOLA[5, 2] was the first who described the fluidisation technique for the separation of ores. The name fluidisation has been used for 15 years.

In the great number (~300) of publications on fluidisation, those on heat and mass transfer in a fluidised bed—briefly summarised below—show great divergencies in their results. In the opinion of the present authors, the reason for this could lie in the fact that the point-porosity in the bed had not been measured and used in the evaluation of these results. It was therefore decided to measure this point porosity in a fluidised bed and to use the values obtained for the calculation of the partial heat and mass-transfer coefficients. The first part of the research will be presented in this paper. For the nomenclature, see references [6, 7, 8 and 9].

Survey of Literature

A. MASS AND HEAT TRANSFER

The literature reviewed covers steady-state and non-steady-state heat transfer, and also quasi-steady-state and non-steady-state mass-transfer. For steady-state heat transfer EICHORN and WHITE[10] carried out experiments on the dielectric heating of plastic particles in a fluidised bed. No temperature differences between gas and solid particles could be measured. KETTENRING, MANDERFIELD and SMITH[11] calculated a heat-transfer coefficient by integration over the total height of a fluidised bed of silica gel (and alumina) and air. The surface area of the particles for unit of height was assumed to be constant. The same assumption has been made by WALTON, OLSON and LEVENSPIEL[12] for experiments with fine powdered coal. However, this supposition has not been supported by experimental proof.

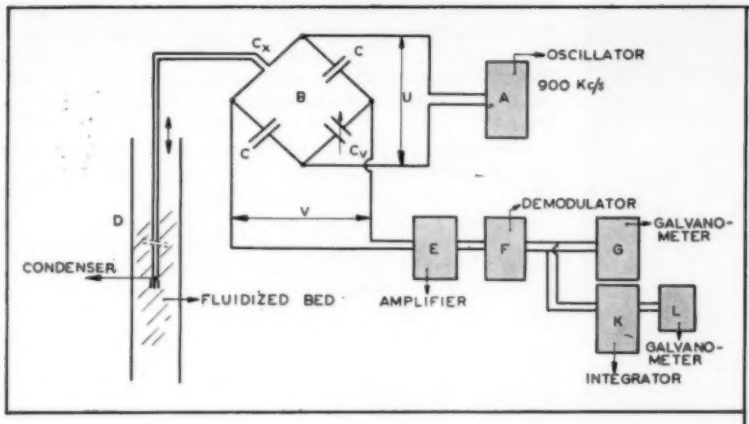
Prof. Dr. Ir. P. M. Heertjes *is professor of chemical engineering in the department of chemical technology of the Technical University of Delft.* **Ir. P. J. Bakker** *is a member of the staff of the laboratory of chemical technology in the same university.*

Symbols*

A = cross-sectional surface of the fluidisation column (cm²);
C = standard capacity (pF);
C_v = variable capacity (pF);
C_x = capacity to be measured (pF);
$C1, 2$ and 3 = constants, respectively no dimension, 1/cm and no dimension;
D = dielectric constant (no dimension);
D_0 = constant (coulomb² sec²/kgm³);
D_t = diameter of the fluidisation column (cm);
G = weight of solid substance in the fluidised bed (g);
L = height of the fluidised bed (cm);
L_{mf} = height of the bed at incipient fluidisation (cm);
L_v = height of the bed at zero velocity (cm);
S = surface of the condenser plates (cm²);
V = fluidisation velocity (cm/sec.);
V_{mf} = minimum fluidisation velocity (cm/sec.);
d = distance of condenser plates (cm);
d_p = particle diameter ($\mu = 10^{-4}$ cm);
h = height in the fluidisation column (cm);
r = radius in the fluidisation column (cm);
$\triangle L$ = bed expansion (cm);
ϵ = porosity (no dimension);
$\bar{\epsilon}$ = mean porosity (no dimension);
ϵ_d = porosity of the fluidised bed in region II (no dimension);
ϵ_{mf} = porosity of the fluidised bed at incipient fluidisation (no dimension); and
ρ_s = density of the particles (g/cm³).

* With the exception as to the velocity (V), the nomenclature as suggested by Murphy[6] will be used; see also reference 7. For the identical German and French nomenclature, see references 8 and 9 respectively.

WAMSLEY and JOHANSSON[13] carried out experiments for non-steady-state heat transfer in fluidised beds of different materials. The heat-transfer coefficient was based on the total height of the bed. Seen in the light of the work of HEERTJES, DE BOER and DE HAAS VAN DORSSER[14] and of HEERTJES and MCKIBBINS[15] on drying of wetted silica gel, where it was found that drying in the so-called constant rate-period took place only over a much smaller height than the total height of the fluidised bed, this supposition is open to doubt.



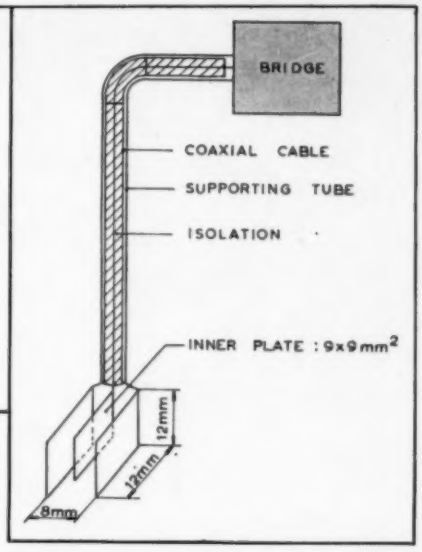


Fig. 1 (above). Apparatus for determining point porosities within a fluidised bed. Fig. 2. Details of the measuring condenser used in the apparatus for determining point porosities in a fluidised bed.

Several authors[11, 12, 13] have tried to establish a general correlation between the heat-transfer coefficients for heat exchange between particles and fluid and some of the fluidisation variables. In spite of the (often confusing) use of a number of dimensionless groups agreement between the results of different authors has not been obtained. Not only for heat transfer between particles and fluid, but also for heat transfer of a fluidised system to or from a heating or cooling surface the published results are in disagreement. BRÖTZ[16] shows that, depending on the method chosen, heat-transfer coefficients have been measured varying from 20 to 2000 k cal/m² hr °C. The contradictory results obtained can mainly be ascribed to the supposition of a uniform heat-exchange area per unit volume—that is, of a constant porosity—throughout the whole fluidised bed.

For mass transfer, EVANS and GERALD[17] determined the transfer of benzoic-acid from fluidised particles to water, MCCUNE and WILHELM[18] for β-naphthol to water, both for non-steady-state conditions. The agreement between these investigations is reasonable. In both cases the fluidisation was effected by a liquid, for which it is known that the stream pattern is nearly homogeneous, so that in this case the chance for agreement is much greater than for mass transfer in fluidisation with a gas. This is supported by comparing the experiments of RESNICK and WHITE[19] for naphthalene in air, hydrogen and carbon dioxide; of HSU and MOLSTAD[20] for the adsorption of carbon tetrachloride from helium-nitrogen mixtures to active carbon; of CHU, KALIL and WETTEROTH[21] for the transfer of naphthalene from particles to air; and of KETTENRING *et al.*[11] for transfer of water from silica gel to air.

GAMSON[22] has tried to correlate a number of measurements on mass transfer with the aid of a constant porosity-term. However, he did not succeed in establishing a satisfactory correlation.

As mentioned earlier, it seemed likely to the present authors that the discrepancy of the results reported was caused by the assumption of constant porosity over the whole bed and by the failure to recognize that mass and heat transfer in general do not take part over the entire fluidised bed.

B. Porosity in a Fluidised System

A short review will now be given in chronological sequence of the literature of the actual porosity measurements or analogous methods in a fluidised bed and of the techniques used.

In 1949 REISS[23] published a method for determining the concentration of particles in a gas. The method consisted of passing a limited light-beam through a suspension of particles in air; the emitted light was caught by a photocell and the photo-current was made visible on a cathode-ray oscillograph. This method can only be used for dilute suspensions and, moreover, it gives a mean value for the porosity. The method of REISS, therefore, cannot be used to measure point porosities in a fluidised system. However, the automatic determination of catalyst losses in a cracking plant using a fluidised bed can be based on the method of light absorption (see RAMSER and HICKEY[24, 25]).

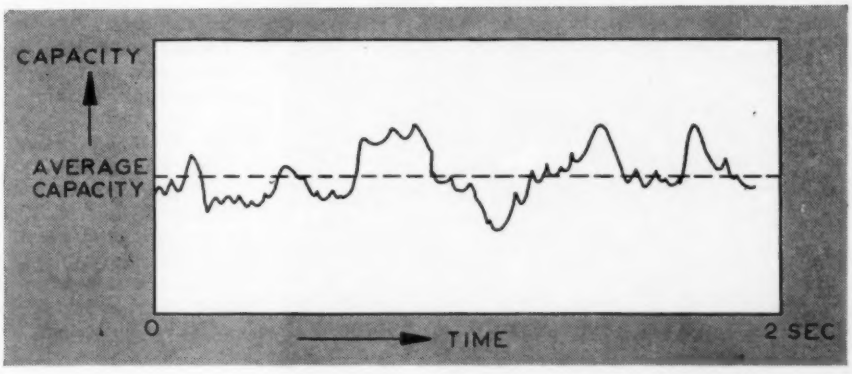
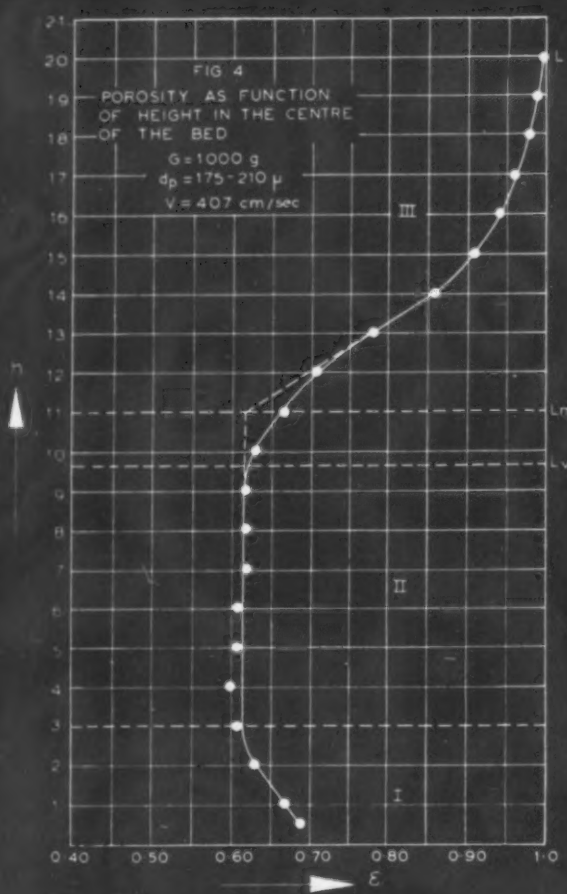
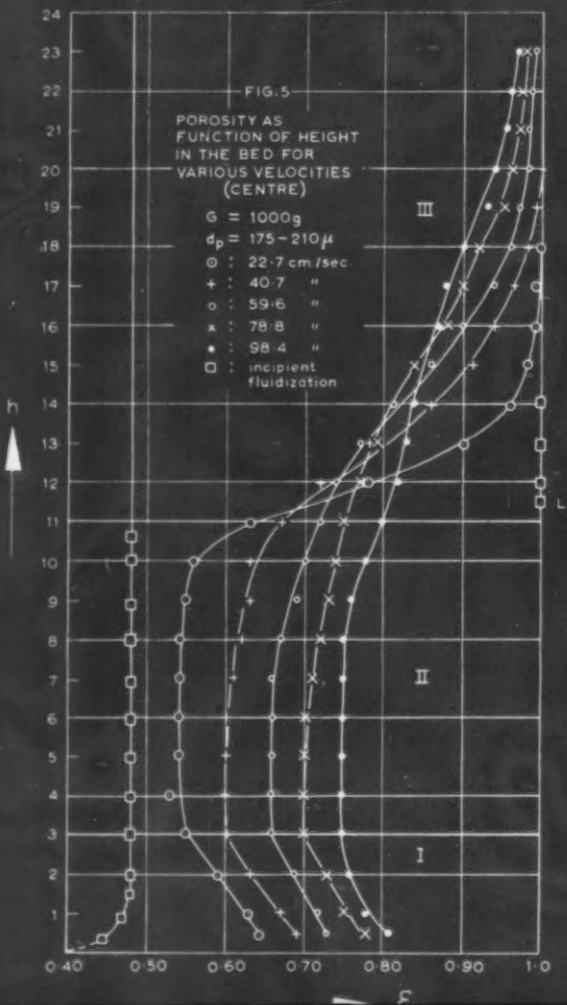


Fig. 3. Typical chart showing how capacity varies with time in a fluidised column.





The necessity to record and to control catalyst losses as well as the bed level in a fluidised-bed reactor has led to other methods of measurements. In most cases these measurements of the particle concentrations have been made in the dilute phase just above the actual fluidised bed.

The capacitive method of DOTSON *et al.*[26] may be mentioned; this method is based on the change of the capacity of a condenser and is described later.

For the control of the bed level, OSBERG[27] applied the so-called hot-wire method, based on the difference in heat transfer from a hot wire to a fluidised bed and to the fluidising gas. Another method for determining the bed level uses γ-rays.[28].

The capacitive method of DOTSON has been used by MORSE and BALLOU[29] to determine the fluidisation uniformity in different points of a bed expressed in a uniformity index of fluidisation. They showed sharp changes in capacity at each point in a fluidised bed. Therefore, it can be concluded that rapidly changing porosities occurred in each point of the bed. However, MORSE and BALLOU did not calculate porosities from their measurements.

Similar results have been obtained by GERALD,[30] who used a piezoelectric crystal to transmit the impulses from a diaphragm placed in the fluidised bed (microphone method). According to GERALD, this method is preferable to that of MORSE and BALLOU, because its use is not restricted to non-conducting materials.

Working along lines similar to those of MORSE and BALLOU, MARTIN and ANDRIEU[31] have used the capacitive method for correlating the fluidisation uniformity with a number of fluidisation variables. The uniformity-index of fluidisation introduced by MORSE and BALLOU has also been investigated by SHUSTER and KISLIAK,[32] who called it the fluidisation quality. The technique used is the measurement by means of stress-strips of local pressure differences caused by concentration changes. The results of MORSE and BALLOU were confirmed. A short communication of REBOUX[33] indicates the use of a method intermediate between that of MORSE and BALLOU and that of SHUSTER and KISLIAK, but no results are given.

From the papers on the overall density of a fluidised bed determined with the aid of X-rays as given by GROHSE[34] and BARTHOLOMEW and CASAGRANDE,[35] no conclusion of point-porosity can be drawn. The light-absorption method of REISS has been used by GOPICHAND, SARMA and NARASINGA RAO[36] for the calculation of a quality index of fluidisation.

So far no publication on the direct determination of the point-porosity in a fluidised bed has been found.

C. STREAM-PATTERNS IN A FLUIDISED BED

In the experimental work to be described some conclusions as to stream-patterns will be drawn. Some of the more important publications in this field will therefore be given.

TOOMEY and JOHNSTONE[37] considered a fluidised bed to be composed of a discontinuous dilute phase (rising gas bubbles) and a continuous dense phase. The discontinuous phase carries none or very few particles. The size of these rising gas bubbles increases while passing through the bed, as has been demonstrated by MATHESON, HERBST and HOLT[38] and by WICKE and HEDDEN.[39]

It was verified by JOHNSTONE, BATCHELOR and SHEN[40] for the case of the oxidation of NH_3 and by SHEN and JOHNSTONE[41] for the catalytic decomposition of N_2O in a fluidised bed that a considerable amount of fluidising gas passed the bed without reacting; this phenomenon has been named by-passing. An analogous result has been obtained by ASKINS, HINDS and KUNREUTHER[42] on experi-

ments concerning the regeneration of catalyst with oxygen in a commercial fluidisation regenerator. Taking samples at short time intervals, strongly differing amounts of oxygen were found, depending whether the sample was taken from the dilute or from the dense phase. Experiments on the oxidation of NO by GILLILAND and MASON[43] confirmed the above. The same authors [44, 45] demonstrated back mixing of gas in a fluidised bed with experiments on the injection of He and CO_2 in a fluidised bed. It was found that a main gas stream moved upwards in the centre of the bed, and that back mixing took place along the walls of the bed. Contrary to the explanation of back mixing as a flow phenomenon, VAN HEERDEN[46] explains the back mixing by adsorption of gas on the particles. With particles of small adsorbing capacities, a smaller degree of back mixing was found than with strongly adsorbing particles.

Several authors [47, 48, 49, 21] have found that a stream of particles rises in the centre of the bed and moves downwards along the walls of the fluidised bed, producing a whirling motion of the particles.

The Determination of a Point Porosity*

From the literature survey it can be concluded that the capacitive method gives reasonably reproducible and accurate results. The volume of the condenser can be chosen to be small compared with the volume of the bed; the porosity deduced from the measurements will therefore approach a point porosity. A disadvantage of the method is that an alien body is introduced into the bed which may disturb the type of fluidisation.

The capacitive method, despite this disadvantage, was used in this investigation. Not only does it afford a close approach to values of point porosity, but it is accurate, easily reproducible and allows continuous measurements to be taken.

The capacity of a plate condenser placed in a homogeneous mixture of two components with different dielectric constants will depend on the amounts and on the dielectric constants of the components. For heterogeneous mixtures, such as a gas and solid particles, the mutual orientation of the two phases is also important. If the orientation of the particles is known, the capacity of the condenser is a measure for the porosity. In the calibration of the condenser it has been assumed that between the plates the solid particles were uniformly distributed in the air.

The capacity of the condenser (C_x) has been measured by means of a Wheatstone's bridge. The condenser was made relatively small compared with the volume of the bed. This had the additional advantage that it disturbs the bed only slightly. The plate surface used was ~1 cm². Since very small capacity changes had to be measured, a very sensitive measuring device had to be used. A sketch of the whole experimental set-up is given in Fig. 1.

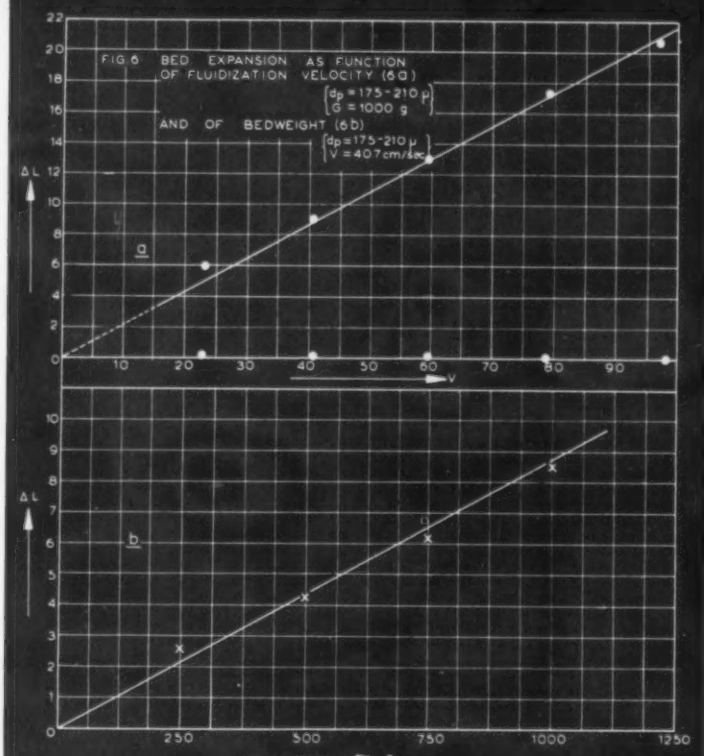
An oscillator (A) feeds the bridge (B) with a high-frequency voltage (U) (900 kc/sec). The bridge consists of the measuring condenser C_x, placed in the fluidised bed (D), the variable condenser, C_v, and the two standard condensers (C). If the bridge is not in equilibrium, a signal V is given for which:

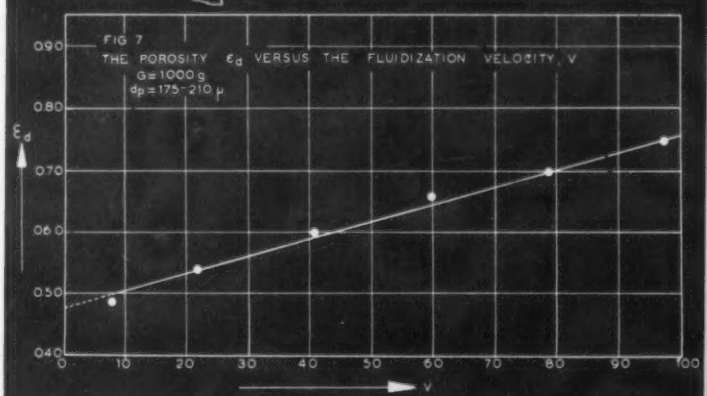
$$V = \frac{C_v.C_x - C^2}{(C_v + C)(C_x + C)} \cdot U \qquad \ldots.(1)$$

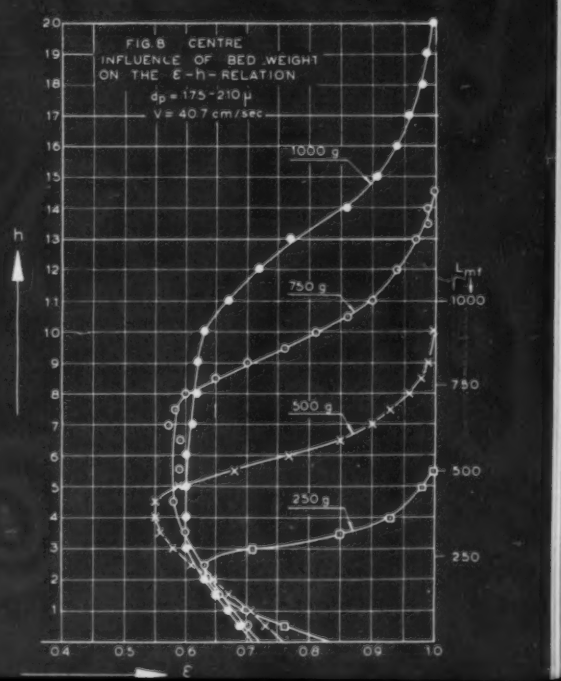
For $V = 0$, that is, if no signal is given, it follows that $C^2 = C_v.C_x$.

The instrument has been used in such a way that when the measuring condenser was placed in air no signal was

* *The porosity of a fluidised bed will be defined as the ratio of the volume of the fluid to the total volume of the bed, e.g.* $\bar{\varepsilon} = 1 - \frac{G}{A.L.\rho_s}$







given. Therefore, C_v was adjusted to this situation and kept constant during the whole series of measurements. If, moreover C is chosen $\gg C_x$, the relation between V and C_x will be almost linear for a chosen constant value of C_v. The proportionality constant has been determined by calibration.

The signal V is amplified by means of the amplifier (E), demodulated (F) and measured with galvanometer (G), which also acts as a zero indicator, or with galvanometer (L) after a rapidly alternating signal (see below) has been integrated by means of (K).

The construction of the measuring condenser is given in Fig. 2. The condenser consists of three flat copper plates; both the external plates are earthed, the inner plate carries the voltage. By means of a co-axial cable (capacity C''_x) the condenser is connected with the bridge.

The capacity of a flat-plate condenser C'_x $(= C_x - C''_x)$ is given by the expression:

$$C'_x = \frac{D_o.D.S}{4\,\pi\,d} \qquad \ldots.(2)$$

where D_o = constant, depending on the chosen system of units;
D = dielectric constant of the medium between the plates of the condenser;
S = surface area of plates; and
d = distance of plates.

For air, $D = 1$ and $D_o = 1/9 \times 10^{-9}$ the condenser used has a capacity of $C'_x = 0.36$ pF.

For a fixed bed of glass beads with a dielectric constant of about 7, of uniform porosity of 0.40, a capacity of about 1.70 pF will be found. If, therefore, porosity changes of 0.01—equivalent to about 1500 particles of 200μ—in the region mentioned are to be found, it is necessary to measure the capacity with an accuracy of at least 0.02 pF. This necessitates the use of a very sensitive apparatus. Further details about the construction will be omitted here. They will be published along with the diagram showing the relation between the diameter and porosity in the thesis of P. J. BAKKER.

In the measurements it appeared that, at a fixed place, the porosity, and therefore the capacity of the condenser, changed rapidly but rather regularly with time around a mean value. An example is given in Fig. 3. For the evaluation of the results, only the mean value has been taken. The integration has been carried out automatically by means of (K), as described.

The fluidisation column used was made of brass with a supporting sieve of nickel gauze. Beneath the supporting sieve was a calming section, consisting of a layer of Raschig rings on a sieve of copper. The amount of fluidisation gas (air) was measured with a Rotameter. The measuring condenser could be moved in the fluidisation tube in a vertical and in a horizontal direction to a fixed position. The fluidised substance consisted of glass beads. Narrow-range sieve fractions were used.

The measured capacities have been translated into porosities by means of a diagram showing the relation between the porosity and D; the evaluation of this diagram will be published in another place. It has been based on a calibration using systems of known porosities with a uniform distribution of the particles.

Experimental Results

For particles of a diameter of 175-210μ,* a bed weight of 1000 grammes and a fluidisation velocity of 40.7 cm/sec., the porosity in the bed has been measured at different heights in the centre of the column. Fig. 4 shows the results obtained which have been connected by a drawn line. The upper two horizontal dotted lines indicate the upper layer

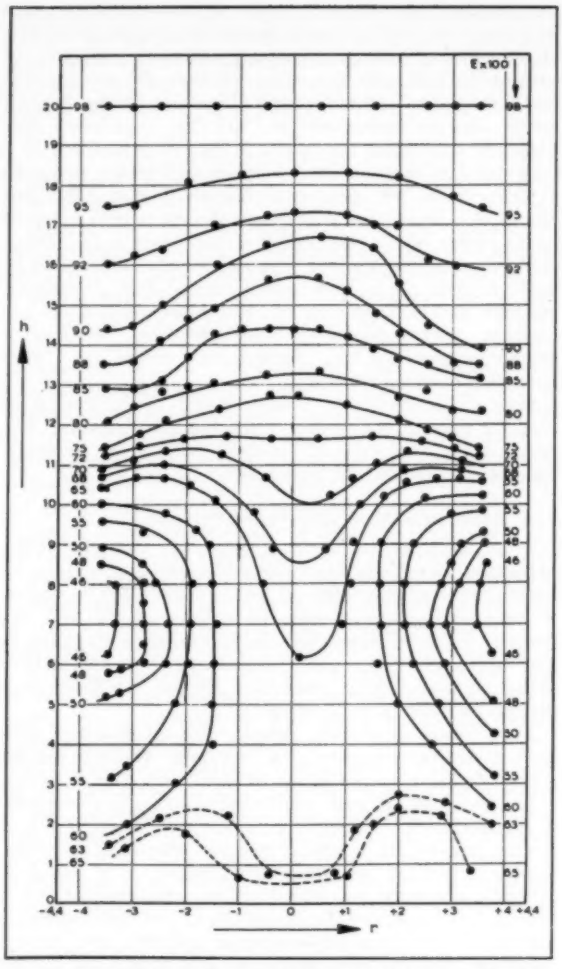


Fig. 9. Isopore diagram for a fluid rate of 59.6 cm/sec. particle diameters 175-210μ and bed weight G equal to 1000 gm.

of the fluidised bed in rest ($\bar{\varepsilon} = 0.40$; $h = L_v$) and the top of the fluidised bed at incipient fluidisation at the minimum fluidisation velocity ($\bar{\varepsilon} = 0.476$, i.e., the loosest packing possible for spheres, $h = L_{mf}$). The minimum fluidisation velocity is the minimum velocity of the fluid necessary to set the particles in whirling motion.

The form of the line indicates the existence in the centre of the bed of three main regions. In the first region, which we will call the sieve effect region (I), the porosity diminishes with increase of height in the bed. This is probably due to the lifting effect of the airstream entering the bed. This lifting force causes a closer packing of the bed, until an equilibrium is reached at region II. This region II is characterised by a constant porosity. Between regions II and III ($L_v \rightarrow L_{mf}$) a transition region is found. In region III the porosity increases gradually to unity. Fig. 4 shows that the assumption of constant porosity of a fluidised bed (as often to be found in the literature) is incorrect. The type of line in region III can best be described by a probability function of the form:

$$1 - \varepsilon = C_1 \,.\, e^{-C_2 \,.\, (h - L_{mf})^{C_3}} \qquad \ldots.(3)$$

C_1, $_2$ and C_3 are constants which depend on the velocity, the particle size and the bed weight.

The influence of the fluidisation velocity on the $h - \varepsilon$

* *The measures given are the corresponding sieve measures.*

function is shown in Fig. 5. For increasing velocities the $h - \epsilon$ line in region II (as well as in region I) moves to the $\epsilon = 1$ axis. The point at which the $h - \epsilon$ lines in region III reach the $\epsilon = 1$ axis will be called, as usual, the fluidised bed height L. The bed expansion $\triangle L$ is defined

$$\triangle L = L - L_{mf} \qquad \ldots . (4)$$

The relation between $\triangle L$ and the fluidisation velocity V as found is given in Fig. 6 (a). The influence of the bed weight G on the bed expansion is given in Fig. 6 (b).

The lines of region III from Fig. 5 can all be expressed by Equation (3). The influence of the air velocity on the porosity ϵ_d of region II is shown in Fig. 7, from which follows in approximation:

$$\epsilon_d - \epsilon_{mf} = C.\ (V - V_{mf}) \qquad \ldots . (5)$$

because the relation is almost straight and ϵ_d approaches ϵ_{mf} when V approaches V_{mf}.

The amount of fluidised substance has no marked influence on the type of the $\epsilon - h$ lines, with the exception of region II, which region, by decreasing the amount of substance, decreases in height up to a bed weight of 500 grammes, where region II disappears completely. An illustration is given in Fig. 8 in which, for four different bed weights, the $\epsilon - h$ relation has been traced. It shows that region III, regardless of the fact whether there is a region II, starts at the bed height at incipient fluidisation. Moreover, there is a tendency for the constant porosity lines of region II, or in absence of region II the porosity at the intersection of region II and region III, to show a minimum as a function of the bed weight.

Experiments with spherical particles of glass of other sizes as well as with other materials with different density and different form, such as silica gel, show the same phenomena as given above.

In order to get a general impression of the porosity distribution in a fluidised bed, measurements have been extended to the whole bed. It has been found that a radial uniformity was present in the column and, therefore, final measurements were carried out only in a vertical plane through the axis. In this way the porosities as a function of height and radius of the column can be found. Connecting points with equal porosity by lines, a diagram with lines of equal porosity—*isopores*—is obtained. These isopores give a good impression of the streaming pattern in the column. In Fig. 9 an example of such an isopore-diagram has been presented.

The method chosen necessitates the introduction of an alien body into the fluidised bed. It is quite conceivable that this procedure would create disturbances in the general flow pattern. It has, however, been found by integrating the $\epsilon - h$ curves that the mean porosity value obtained in this way was in all cases within 8% as a maximum (±) equal to the calculated porosity based on the height of the bed.

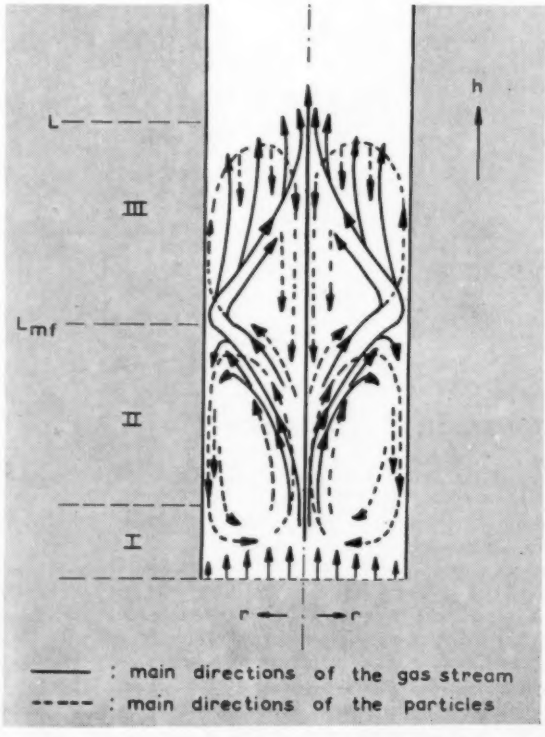


Fig. 10. Flow pattern in a column containing a fluidised bed.

Discussion

As mentioned above, according to TOOMEY and JOHNSTONE a fluidised system consists of two phases—a phase of rising gas bubbles and a continuous phase of particles and gas with a porosity equal to the porosity at incipient fluidisation. An increase in fluidisation velocity causes an increase of the amount of gas bubbles present in the bed. This should be accompanied by an increase of the average porosity in the bed. This has indeed been found as demonstrated in Fig. 4 for the regions I and II. The relation between ϵ_d and V as presented in Fig. 7 has been expressed by Equation (5), in which it is assumed that at a fluidisation velocity approaching its minimum, the porosity of the bed (ϵ_d) will equal ϵ_{mf}, i.e., the porosity at incipient fluidisation, the loosest packing of spheres possible. For a monodisperse system this should be the cubical packing with a porosity ϵ_{mf} of 0.476.

It has to be observed, however, that the system is not monodisperse, which creates a difficulty as to the actual minimum fluidisation velocity as well as to the value of ϵ_{mf}. Moreover, vibrations which are almost always present will disturb any packing.

It is remarkable that by extrapolating the linear relation between ϵ_d and V, to $V = 0$, a value of ϵ_d of 0.48 is found. This is a rather peculiar coincidence.

Region I does not allow for much discussion. Clearly, the type of sieve used and an entrance effect caused by the change in packing have a large influence on form of the lines and height of the region.

At velocities larger than the minimum fluidisation velocity, gas bubbles in increasing number ascend in the bed. These bubbles contain particles. As soon as such a bubble breaks the surface of the bed, the particles confined in and around the gas bubbles are thrown into the region above the bed proper, forming region III. It is likely that the impulse with which the particles are thrown up into region III will depend on the velocity of the gas bubbles (which again depends on the size of the bubbles). The amount thrown up will depend on the number of bubbles and on the amount of particles in one bubble. A probability function between the amount of particles and the height in region III will, therefore, exist as expressed in a general form in Equation (3).

It has been found for one particle size that the constants C_1 and C_2 both depend on the fluidisation velocity, while C_3 is nearly equal to 1.3. The parameter L_{mf}, of course, is a function of the bed weight.

Fig. 6 (a) demonstrates that the bed expansion increases with fluidisation velocity, which is normal. The relationship found, however, is not easily understood. The same holds for the linear relationship between bed expansion and bed weight. It may be observed that the rising gas bubbles show a tendency to grow on their way up through the bed by

coalescence. This causes an augmentation of the bubble velocity and, therefore, an increase of the particle impulse above region II, i.e., a larger bed expansion. The diameter of the bubbles increases directly proportional to the height of the bed, that is, proportional to the bed weight. This does not, however, immediately explain the linear relation between $\triangle L$ and G (Fig. 6 (b)).

A peculiar phenomenon is encountered by plotting ϵ_d (or its equivalent if no region II is present) as a function of G as deduced from Fig. 8, by which procedure a minimum appears. This can be explained by the influence of the ratio of bed height over bed diameter on the fluidisation phenomena. It is a well-known fact that for high ratios of L_{mf}/D_t slugging occurs. Slugging causes an increase of the average porosity. Without slugging ϵ_d will decrease, i.e., give a closer packing in region II (and I) with increase of the bed weight. Above a certain bed weight slugging will occur and increase (up to a certain maximum) with increasing bed weights. In this region the increase in porosity by slugging can be larger than the decrease by bed weight alone. This can explain the minimum found.

Experiments with silica gel with a lower density than glass have shown that the minimum occurs at relatively much lower bed weights, as would be expected.

An illuminating picture of the porosity in a fluidised bed is given by Fig. 9. The overall flow pattern in the bed can be deduced from the isopores presented. This is given in Fig. 10, where the full drawn lines represent the main direction of the gas stream and the dotted lines the main direction of the flow of the particles. The whole is symmetrical with respect to the centre line of the tube. In the opinion of the authors, the typical flow pattern is caused by the influence of the wall and might be changed considerably for larger containers.

Experiments with other fluidisation velocities and other bed weights give slightly different flow patterns, but of the same general type.

Conclusions

No direct point porosity measurements in a fluidised bed have been carried out so far. It has been found that the assumption of a constant porosity through the whole of a fluidised bed supported by a sieve is incorrect. Such a fluidised bed in its centre is built up of three regions—the sieve effect region (I), a region of constant porosity (II) and a third region in which the porosity increases from the value in region II to unity. For region I no mathematical relation between porosity and height has been given, for region III this relation takes the form of a probability function.

The constant porosity in the second region changes linearly with the fluidisation velocity. Due to slugging effects the porosity in region II shows a minimum as a function of the bed weight. The height at which region II changes to region III is equal to the initial height of the bed at incipient fluidisation.

The bed expansion, that is the height of region III, changes linearly with the fluidisation velocity and with the bed weight. Near the wall the picture is different, which can be deduced from the porosity measurements over the whole bed. A general flow pattern for the gas, as well as for the particles, has been derived from these measurements (see Fig. 10).

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Summer School on Distillation Techniques

THE Department of Chemical Engineering, Loughborough College of Technology, is to hold a Summer School on Distillation Techniques, to be held in the College's Department of Chemical Engineering from July 15 to 24 inclusive. The course will cover the major design techniques in the field of distillation up to or beyond the level of the usual undergraduate honours course. The syllabus proposed is as follows:

Part 1. Equilibria and thermodynamics;

Part 2. Stagewise calculations; and

Part 3. Plant design.

The subject-matter of the lectures in the programme will be supplemented by tutorials on each subject to give practice in the solution of difficult problems. Parts 1 and 3 will also be extended by practical work in the laboratories of the department and will include a choice of the following: determination of vapour-liquid equilibria by boiling-point methods and with equilibria stills for ideal and non-ideal systems; efficiency in loading determinations on plate-type and packed columns; investigations of boiling and condensation heat-transfer coefficients for binary systems; and control experiments using an air analogue unit.

The fee for the course, including residence at a college hotel, is 30 guineas, and forms of application can be obtained from the Registrar, Loughborough College of Technology, Loughborough, Leicestershire.

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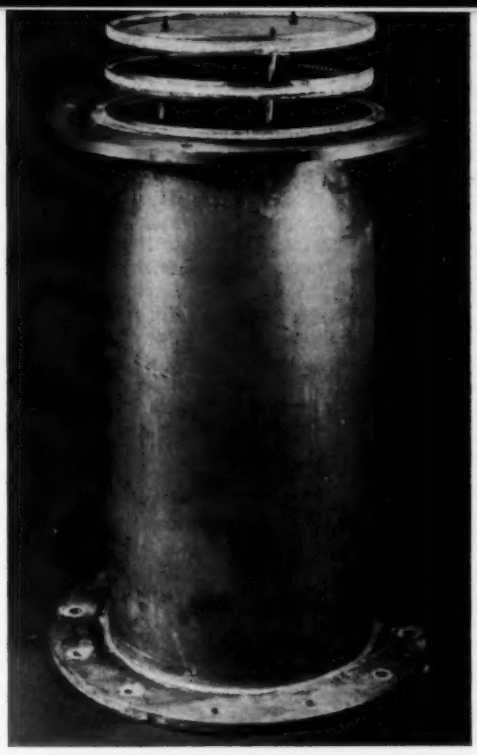

Fig. 1. Section of a 12-in. diameter column showing the method of plate assembly.

PULSED PLATE LIQUID-LIQUID EXTRACTION COLUMNS

by J. D. THORNTON, Ph.D., F.R.I.C., A.M.I.Chem.E.

Pulsed-plate columns are being increasingly used for liquid-liquid extraction processes. A method of designing this highly efficient type of contactor is described

Symbols Used

A = pulse amplitude (i.e., total excursion in column) (ft);
d_o = diameter of holes in sieve-plates (ft);
f = pulse frequency (cycles/hr);
g = acceleration due to gravity (ft/hr^2);
g_c = gravitational conversion factor ($= 4.17 \times 10^8$) (lb. (mass) ft/lb. (force) hr^{-2});
h = plate spacing (ft);
$(H.T.U.)_o$ = overall height of a transfer unit (ft);
K = constant (dimensionless);
S = cross-sectional area of column (sq. ft);
V = superficial velocity of phase in column (ft/hr);
$\overline{V}_o$ = characteristic droplet velocity, i.e., mean droplet velocity when $V_c = 0$ and $V_d \rightarrow 0$ (ft/hr);
x = fractional hold-up of dispersed phase (dimensionless);
γ = interfacial tension (lb./hr^2);
ϵ = fractional free-area of sieve-plates;
μ = viscosity (lb./ft hr);
ρ = density (lb./cu. ft);
$\Delta\rho$ = density difference of phases (lb./cu. ft); and
ψ_f = frictional power absorbed per unit mass of fluid in the perforations in the sieve plate (sq. ft/hr^2).

Subscripts

c = continuous phase;
d = dispersed phase; and
f = value at the floodpoint.

Dr. Thornton *has worked upon liquid-liquid extraction problems at the Atomic Energy Research Establishment, Harwell, for a number of years and is now Senior Lecturer in Chemical Engineering, King's College, University of Durham.*

UNTIL comparatively recently, liquid-liquid extraction processes were confined to separations requiring only a moderate number of theoretical stages. This was inevitable in view of the large stage-heights associated with gravity-operated towers. However, during recent years, there has been a renewed interest in liquid extraction processes, particularly for the separation of multi-component mixtures. This has been largely due to the nuclear power industry, where it was recognised that liquid-liquid extraction offered a convenient means of separating inorganic materials, such as the recovery of uranium from leach liquors and the separation of uranium and plutonium from spent reactor fuel elements.[1] Such processes, however, require a comparatively large number of theoretical stages and much effort has been devoted to the development of high efficiency contactors in order to reduce the plant to an economic size, thereby effecting considerable economies in building costs as well as in biological shielding costs in the case of radiochemical separation processes.

In practice, contactor efficiency can be increased by performing mechanical work on the system, thereby increasing the interfacial area available for mass transfer. Although many types of mechanical contactor have been proposed, they can all be placed in one of two categories, depending upon whether a rotary or a reciprocating motion is used to produce the phase dispersion.[10] In the rotary type of contactor, the phases usually flow countercurrently through a column shell which is provided with a coaxial rotor of suitable design, the degree of phase dispersion being controlled by the speed of the rotor. However, such devices are of limited application for radioactive or corrosive systems due to the difficulty of maintaining the shaft seals. Under such conditions it is preferable to use some form of pulsed contactor in which the energy necessary for phase dispersion is communicated to the process liquors by means of a reciprocating or pulsating motion. This is most readily accomplished

by connecting the bottom of the column to a cylinder which is closed by a reciprocating piston. In the case of corrosive systems, the pulsing unit may be located above the hydrodynamic liquid level in the contactor so that the motion of the pulser is communicated to the process liquors via a pocket of air or inert gas. By means of such an "air-pulsing" technique,[9] all mechanical moving parts are remote from the process liquors and the problem of maintenance is greatly simplified.

Although pulsed contactors are ideally suited to corrosive conditions, it is not to be inferred that their use is restricted to such systems and they might, with advantage, be considered for other applications where cheapness, simplicity of construction and compactness of design are of prime importance.

Although a considerable amount of work has been carried out in an attempt to understand the mechanisms underlying mass-transfer processes across liquid-liquid interfaces, it is not possible at the present time to predict mass-transfer rates from first principles. For design purposes, therefore, it is necessary to carry out a limited number of runs in a laboratory-scale column first of all in order to determine the extraction characteristics of the system. Data obtained from such model tests may then be employed directly to predict the performance and throughput of the full-scale unit.

Constructional details of both laboratory and full-scale pulsed columns are described in the present article and it is shown how laboratory data can be used to calculate the leading dimensions of the final contactor.

Constructional Details

Column Shell and Packing

Although work with packed pulsed columns has been reported in the literature, the use of random packings is not recommended for this type of contactor. This is because such packings tend to orientate under pulsed conditions, with consequent loss in extraction efficiency.[6] It is therefore preferable to use some form of fixed packing, such as corrugated discs of expanded metal stacked with the corrugations of adjacent discs at right angles.[7] Alternatively, conventional sieve-plates may be employed. In both cases it is important to ensure that good contact is made at all points with the column wall. Thus corrugated expanded metal packing has the advantage that it can be tamped down at the edges in order to ensure a good fit in the column. On the other hand, once installed, it is not easy to remove for cleaning without inducing some degree of distortion and for this reason conventional sieve-plates offer definite advantages although the first cost is higher. In order to ensure good contact between the plate periphery and the column shell, it is convenient to weld a grooved collar around the rim of the plate which can be fitted with a suitable packing such as asbestos cord in order to provide an effective seal.

In practice it is convenient to assemble the plates in 3-ft "cartridges" using three tie rods provided with spacer-sleeves of suitable length between each pair of plates. A typical sieve plate assembly of this type is shown in Fig. 1. For columns of 3 to 24 in. diameter the plates should be spaced at 2-in. intervals and should be drilled with sufficient $\frac{1}{4}$-in. diameter holes, based on a triangular pitch, to provide a total free area per plate of approximately 25%.

In the case of laboratory columns, it is convenient to construct the column shell from standard lengths of flanged borosilicate glass pipeline, in which case the bore may be rendered uniform by shrinking the glass on to a steel mandril at an elevated temperature under vacuum. Alternatively, sieve plates fitted with sealing rims may be used as described above.

Methods of Pulsing

In theory, mechanical work may be performed on the system by reciprocating the sieve plates or by keeping the plates stationary and pulsing the liquors in the

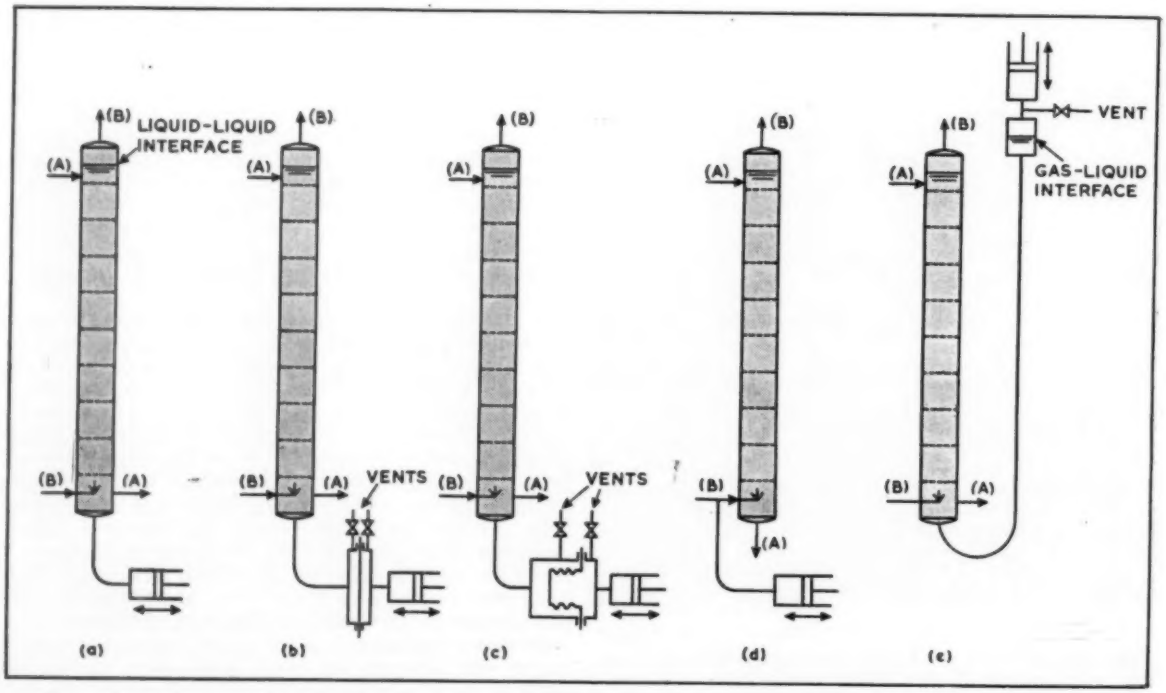

Fig. 2. Block diagram showing five alternative methods of pulsing a column. A = Heavy phase. B = Light phase.

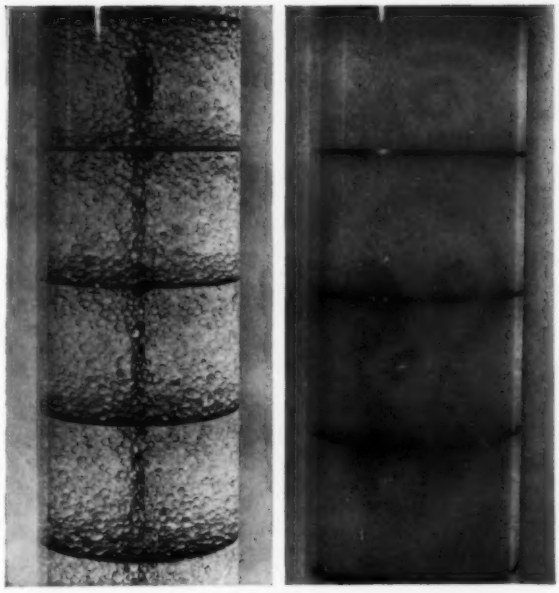

Fig. 3. Effect of pulse energy on droplet size. (a) (left) Low pulse energy. (b) High pulse energy.

column.[11] In practice, the latter method is to be preferred as being mechanically simpler and it is along such lines that modern developments in pulsing techniques have progressed. While it has been shown that sawtooth and semi-square waveforms give improved extraction efficiencies by comparison with a sinusoidal waveform, the latter is preferable in practice because of the mechanical simplicity of the pulsing unit.[8]

If the extraction system is non-corrosive and non-radioactive, the column may be pulsed by a reciprocating piston in direct contact with the process liquors. Such a scheme is shown diagrammatically in Fig. 2 (a). A convenient pulsing unit which delivers an approximately sinusoidal waveform can be made from a plunger pump in which the check valves have been removed. The pump should preferably be driven through an infinitely variable gearbox so that a range of pulse frequencies ranging from 1 to 5 c/s can be obtained. The displacement of the pump should be such that the pulse amplitude (i.e., the total excursion measured in the column) ranges from $\frac{1}{4}$ to 1 in. Such a system cannot, however, be employed under corrosive conditions and various alternatives have been proposed in which the pulsing unit is isolated from the column liquors by means of a diaphragm or bellows as shown in Figs. 2 (b) and (c). In each case the motion of the pulsing unit is transmitted hydraulically to the bellows or diaphragm. While such arrangements serve to prevent the contamination of the pulsing unit by the process fluids, there is always an element of uncertainty attaching to these devices due to the possibility of mechanical failure. In attempts to overcome this difficulty other workers have proposed pulsing a non-corrosive or non-radioactive feed-stream as shown in Fig. 2 (d). Although there is no serious objection to such a proposal during actual plant operation, it is questionable whether such an arrangement is entirely satisfactory during shut-down periods due to back diffusion. These objections can be met by the method of "air-pulsing" developed recently.[9] This is shown simply in Fig. 2 (e). Here the pulsing unit is located above the liquor level in the column, the pulse-line communicating with the bottom of the column via an expansion chamber. The latter minimises the vertical distance traversed by the gas-liquid interface, thereby eliminating the possibility of contamination of the pulsing unit. During operation the motion of the pulser is transmitted to the column by air or an inert gas which is trapped in the pulse line between the gas-liquid interface in the expansion chamber and the piston. Although a proportion of the total energy is lost in performing work on the gas, this is not excessive and 6-in. diameter columns 25 ft high have been pulsed successfully by this means.[7] There is no reason to suppose that this represents the limiting size of column that can be pulsed by such means, and in practice the maximum size is probably dictated by economic considerations.

Whichever method of pulsing is selected, it is essential that friction losses in the pulse line be kept to a minimum, otherwise cavitation and "hammer" will result during operation. It is important, therefore, that the pulse line should have an adequate cross-section and that the number of bends should be reduced to a minimum.

Contactor Design

In the absence of interfacial effects due to solute transfer, it has been shown that, as in the case of rotary contactors, the droplet size range is small for any given set of operating conditions. This is demonstrated by the high-speed flash photographs in Fig. 3, which show the appearance of a 3-in. diameter column under different pulsing conditions.[8] Furthermore, the degree of droplet coalescence in the column is small at the higher pulse energies, so that the statistical mean droplet size, and hence its associated characteristic velocity, $\bar{V}_o$, is constant up to the floodpoint. The latter is, therefore, only a function of the column geometry pulse energy and the physical properties of the system. The droplet characteristic velocity concept has been discussed at length elsewhere[3] and will not be repeated here except to state that it can be regarded as the velocity of the dispersed phase droplets relative to the continuous phase when $V_c = 0$ and $V_d \rightarrow 0$.

The superficial phase flowrates V_d and V_c can be related to the dispersed phase hold-up, x, and the characteristic velocity $\bar{V}_o$ by the expression:

$$\frac{V_d}{x} + \frac{V_c}{1-x} = \bar{V}_o\,(1-x) \qquad \ldots.(1)$$

At the floodpoint, $\left(\frac{d\,V_d}{dx}\right)$ and $\left(\frac{d\,V_c}{dx}\right)$ are both equal to zero; hence, differentiating Equation (1) and setting the differentials equal to zero gives the following expressions for the superficial velocities at the floodpoint[6]:

$$Vd_f = 2\bar{V}_o\,x_f^2\,(1-x_f) \qquad \ldots.(2)$$

$$Vc_f = \bar{V}_o\,(1-x_f)^2\,(1-2x_f) \qquad \ldots.(3)$$

Eliminating $\bar{V}_o$ between Equations (2) and (3) and solving for x_f the dispersed phase hold-up at the floodpoint, gives:

$$x_f = \frac{(L_R^2 + 8L_R)^{\frac{1}{2}} - 3L_R}{4\,(1-L_R)}$$

$$\text{where } L_R = \frac{V_{df}}{V_{cf}} \qquad \ldots.(4)$$

Values of x_f lie in the range 0 to 0.50 and a graphical solution[6] of Equation (4) is given in Fig. 4. This enables the value of x_f to be read off directly for any given value of the floodpoint flow ratio.

Equations (2) and (3) enable the floodpoint curve to be calculated directly. Thus, provided that the characteristic velocity $\bar{V}_o$ is known, assumed values of x_f ranging between 0 and 0.5 are substituted into Equations (2) and (3) and corresponding values of V_{df} and V_{cf} determined.

Column Diameter

The droplet characteristic velocity has been correlated

for pulsed plate-columns in terms of the column geometry, physical properties of the system and the pulse characteristics by the relationship[8]:

$$\left(\frac{\bar{V}_o\,\mu_c}{\gamma}\right) = 0.60\left(\frac{\psi_f\,\mu_c^5\,g_c}{\rho_c\,\gamma^4}\right)^{-0.24}\left(\frac{d_o\rho_c\,\gamma}{\mu_c^2}\right)^{0.90}\left(\frac{\mu_c^4 g}{\triangle\rho\,\gamma^3}\right)^{1.01}\left(\frac{\triangle\rho}{\rho_c}\right)^{1.80}\left(\frac{\mu_d}{\mu_c}\right)^{0.30} \quad \ldots.(5)$$

For a sinusoidal pulse waveform, the frictional power dissipated per unit mass of fluid is given approximately by:

$$\psi_f = \frac{\pi^2\,(1-\varepsilon^2)\,(f\,A)^3}{0.72\,g_c\,\varepsilon^2\,h} \quad \ldots.(6)$$

In principle, therefore, the appropriate value of $\bar{V}_o$ can be caluculated from Equation (5) for any specified system and operating conditions and the floodpoint curve calculated using Equations (2) and (3). However, the value of $\bar{V}_o$ predicted by Equation (5) is only true in the absence of an undistributed solute, i.e., in the absence of mass transfer. If solute transfer takes place from the aqueous to the solvent phase, then the value of $\bar{V}_o$, compared with that of the solute-free system, is lowered by some 10-15%. On the other hand, if solute transfer takes place from the solvent to the aqueous phase, the equilibrium droplet size is greatly increased and $\bar{V}_o$ is enhanced by some 200 to 300% compared with the value calculated from Equation (5).

At the present time, these effects are not capable of a quantitative interpretation; so, for the purposes of design, it is convenient to determine the enhancement in $\bar{V}_o$ for any given system by carryng out a limited number of runs in a laboratory-scale column. Once the degree of enhancement has been determined, values of $\bar{V}_o$ calculated from Equation (5) need only be multiplied by an "enhancement factor" before being used in Equations (2) and (3) to predict the column diameter.

In practice, it is necessary to carry out only a limited number of mass-transfer runs at various phase flowrates and to measure the fractional hold-up of the dispersed phase at the conclusion of each run by the displacement method.[2]

The procedure for calculating the column diameter for any given set of design and operating variables can therefore be summarised as follows:

(a) Plot the hold-up data in accordance with Equation (1) in the form $\left[V_d + \frac{x}{1-x}.V_c\right]$ as ordinate versus $x(1-x)$ as abscissa. The experimental value of $\bar{V}_o$ can then be obtained directly from the slope of the curve, drawn through the origin.

(b) The value of $\bar{V}_o$ is next calculated from Equation (5) and the ratio of the experimental to the calculated value determined. This ratio, defined as the enhancement factor F, is a measure of the enhancement in $\bar{V}_o$ due to solute effects. Thus:

$$F = \frac{\text{measured } \bar{V}_o}{\text{calculated } \bar{V}_o}$$

Although F is probably a function of the solute driving-force, and would therefore be expected to change over the length of the column, in practice such variations can be neglected for purposes of design so that F can be regarded as substantially constant over a wide range of operating conditions. In the case of solute transfer from water to solvent, F will be approximately equal to unity, but when mass transfer takes place in the reverse direction, F may be of the order of 2 to 3.

(c) Incorporating the enhancement factor into Equations (2) and (3) and writing the superficial velocities in terms of the volumetric flowrates and the column cross-sectional area, S,

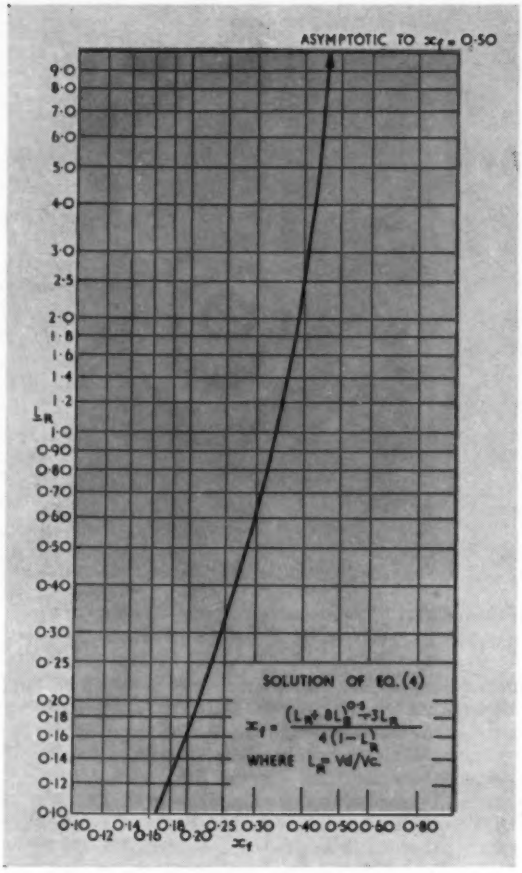

Fig. 4. Graph enabling the value of x_f to be read off directly for any given value of the floodpoint flow ratio.

$$(q_d)_f = 2\,S\,F\,\bar{V}_o\,x_f^2\,(1-x_f) \quad \ldots.(7)$$

$$(q_c)_f = S\,F\,\bar{V}_o\,(1-x_f)^2\,(1-2x_f) \quad \ldots.(8)$$

where $\bar{V}_o$ can be calculated from Equation (5) and x_f from Equation (4) or Fig. 4, since $[(q_d)_f/(q_c)_f] = [(V_d)_f/(V_c)_f]$.

Hence, by means of the above equations, the cross-sectional area of the column, S, at which the contactor will just flood can be determined for any particular values of $(q_d)_f$ and $(q_c)_f$. In practice it is recommended that the design be based on a 50% flooding basis, in which case the actual column cross-sectional area will be twice the calculated value.

It should be noted that although the enhancement factor F was determined at only one particular pulse frequency and amplitude, it is in fact substantially constant over a wide range of solute concentrations and hence operating conditions. For design purposes it can therefore be regarded as a factor which is characteristic of the system, so that Equations (7) and (8) can be used to determine the contactor cross-section for other plate geometries and operating conditions merely by calculating the appropriate value of $\bar{V}_o$ from Equation (5).

It is noteworthy that in the case of pulsed plate-columns, the effect of column diameter upon $\bar{V}_o$ is negligible.[5] The limiting throughput can therefore be scaled up geometrically with column diameter, provided that the other variables are kept constant.

Column Height

(a) The overall continuous phase *H.T.U.* can be correlated by the expression[8]:

$$\frac{(H.T.U.)_{oc}}{(\mu_c^2/g\ \rho_c^2)^{\frac{1}{3}}} = K\left(\frac{\mu_c\, g}{F^3\ \bar{V}_o^3\ (1-x)^3 \rho_c}\right)^{\frac{2m}{3}} \left(\frac{\triangle\rho}{\rho_c}\right)^{\frac{2(m-1)}{3}} \left(\frac{V_d}{V_c}\right)^{0.50} \left(\frac{V_c^3\ \rho_c}{g\ \mu_c\ x^3}\right)^{0.33} \quad \ldots.(9)$$

where the constant K and the exponent m are characteristic of the system. These constants are readily evaluated by plotting the experimental mass-transfer data on logarithmic co-ordinates in the form:

$$\left[\frac{(H.T.U.)_{oc}\ x}{V_c}\left(\frac{g^2\ \triangle\rho^2}{\mu_c\ \rho_c}\right)^{0.33}\left(\frac{V_c}{V_d}\right)^{0.5}\right] \text{ as ordinate versus } \left[\frac{\mu_c\, g}{F^3\ V_o^3\ (1-x)^3\ \rho_c}\left(\frac{\triangle\rho}{\rho_c}\right)\right] \text{ as abscissa}$$

In Equation (9) F is the enhancement factor determined previously from hold-up measurements and the value of $\bar{V}_o$ is that calculated from Equation (5). The slope of the plot is equal to $(2m/3)$ whilst K is equal to the ordinate when the abscissa is equal to unity.

(b) Having determined K and m, Equation (9) may now be used to investigate the effect upon $(H.T.U.)_{oc}$ of changing the operating and design variables such as pulse characteristics, phase flowrates and plate geometry. All values of $(H.T.U.)_{oc}$ so calculated refer, of course, to a column having the same diameter as the laboratory-scale unit. If Equation (9) indicates that, under certain selected conditions, a value $(H.T.U.)_{oc}$ is associated with a column diameter d_c, then in a large-scale column having a diameter d'_c (calculated from Equations (7) and (8)) the corresponding $H.T.U.$ value, designated $(H.T.U.)'_{oc}$ can be calculated from the expression[5]:

$$(H.T.U.)'_{oc} = (H.T.U.)_{oc}\ e^{0.5\ (d'_c - d_c)} \quad \ldots.(10)$$

It is important to note that, since Equation (10) is *dimensional*, all units must be expressed in ft.

The above relationship relating the overall $H.T.U.$ to the column diameter has been determined for column diameters ranging from 0.25 to 1 ft, and a suitable factor of safety should therefore be employed if this range is greatly exceeded.

Power Consumption

The maximum power consumption of a pulsing unit delivering a sinusoidal waveform can be calculated by the method proposed by Jealous and Johnson[4] and reference should be made to this paper for further details. Although a considerable amount of work still remains to be carried out before the operation of pulsed column contactors is fully understood, the above method of design, based on model tests, is adequate for most purposes, and will enable the various design parameters to be evaluated to within approximately ±15%.

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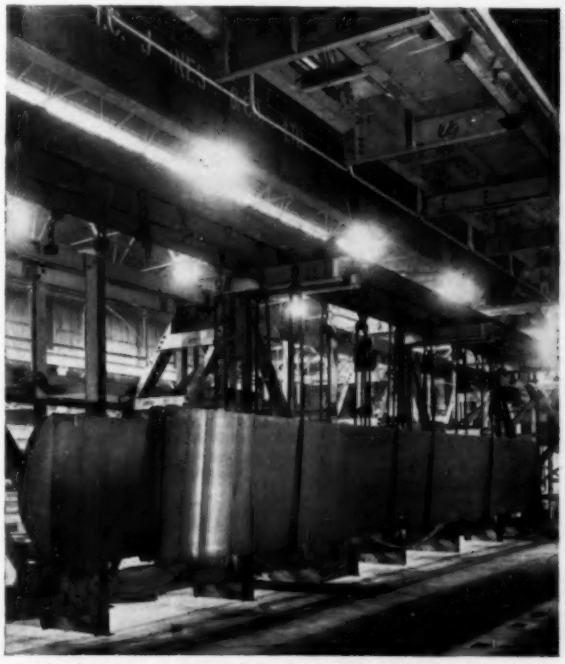
Production of Wide Aluminium Plate

EXPANSION recently completed at the Rogerstone Works of the Northern Aluminium Co. Ltd., near Newport, Monmouth, and plans for £10-millions' worth of further developments recently announced, indicate this company's estimate of the potential growth of the demand for aluminium as a material of construction in engineering, including the fabrication of chemical plant. The availability of 11-ft-wide welded aluminium plate just announced (see British Chemical Engineering, April, p. 226) is one of the results of the commissioning of half-a-million pounds' worth of new plant at Rogerstone. This new machinery includes a plate heat-treatment furnace, a high-speed plate saw for finishing to an accuracy and squareness which it is claimed has never before been attained, and a Curtiss-Wright apparatus for testing thick plate ultrasonically, which embodies a water tank 54 ft × 14 ft × 3 ft deep. Another important unit is the new plate stretcher stress-relieving machine, the biggest of its kind in Europe, having a rated pull of 4000 tons, and capable of applying a controlled stretch to plate up to 50 ft × 10 ft × 6 in., and with a maximum cross-sectional area of 200 sq. in.

When the further developments have been carried out, wide, unwelded plate will be available from the 12-ft-wide hot mill, one of the principal additions to be installed. This will raise the Rogerstone mills output from 45,000 tons to 75,000 tons a year, and room will still be available to raise the capacity by another 100,000 tons.

The plant's new heat-treatment furnace just commissioned was designed and built by Stordy Engineering Ltd. to meet N.A.C.'s detailed requirements. It is bottom-loading, with a quench tank immediately below the furnace chamber and it is lined entirely with stainless steel. Its capacity is nearly 20 tons of plate for ageing at temperatures up to 200°C, without quenching; 10 tons for solution-heat-treatment up to 550°C, with a slow quench; and 5 tons for solution-treatment up to 550°C, with a high-speed quench. Like the rest of the equipment at the works, the furnace is designed to handle plate up to about 50 ft in length, 10 ft wide and 6 in. thick.

The company proposes to spend £2 million of the £10 million development allocation on further modernisation of its Birmingham and Banbury works.



A load of plate being moved in position in the plate heat-treatment furnace.

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PART I.

CONVERSION STAGE IN THE MANUFACTURE OF SULPHURIC ACID BY CONTACT PROCESS

The effect of physical and chemical factors in the catalytic oxidation of sulphur dioxide to the trioxide, including the poisoning of catalysts, is discussed

by G. C. LOWRISON, B.Sc., A.M.I.Chem.E., and F. HEPPENSTALL

THE most critical stage in the manufacture of sulphuric acid is the oxidation of sulphur dioxide to sulphur trioxide. Basically, the reaction is:

$$2SO_2 + O_2 \leftrightharpoons 2SO_3$$

or as it is more usually written to obtain a single molecule of product

$$SO_2 + \tfrac{1}{2}O_2 \leftrightharpoons SO_3 + 22{,}600 \text{ cal.} \qquad \ldots . (1)$$

The reaction is reversible and the maximum degree of formation of sulphur trioxide is determined by the equilibrium of this reaction.

The equilibrium constant, K, is, of course,

$$\frac{K_1}{K_2} = \frac{[SO_3]}{[SO_2]\,[O_2]^{\frac{1}{2}}},$$

where K_1 is the reaction constant for the forward reaction, K_2 that for the reverse reaction.

From the concept of free energy the following equation can be derived:

$$-\frac{\Delta G}{T} = R \log_e K \text{ or } 4.576 \log_{10} K = -\frac{\Delta H}{RT} + \frac{\Delta S}{R}$$

where ΔG is the standard free energy change of the reaction, ΔH is the standard heat of reaction, T is the absolute temperature, ΔS is the standard entropy change and R is the gas constant, the units all being in the cgs system.

When determined values are substituted in this equation the following is obtained:

$$\log_e K = \frac{22{,}600}{RT} - 10.68 \qquad \ldots . (2)$$

This equation may also be written in the form:

$$R\left(\frac{\partial \log K}{\partial(1/T)}\right)_P = -\Delta H \qquad \ldots . (3)$$

It can be used to determine K, since $R \log K$ plotted against $\frac{1}{T}$ is a line of slope ΔH. Hence K can be determined for any temperature.

It is obvious that the dimensions of the quantities used in these equations are important to the value of the equilibrium constant obtained. Fig. 1, in which the concentration of the gases is expressed as partial pressures in atmospheres and in which the equilibrium constant is expressed in these dimensions by the symbol K_P, shows a plot of Equation 2.

As is well known, the partial pressures of these gases can only be used in this equation at comparatively low pressures, such as one atmosphere and below. If very much higher pressures are used it is necessary to substitute fugacities for the partial pressures. This will be dealt with more fully later.

From such a graph as Fig. 1, the degree of conversion at equilibrium can be calculated at any temperature within the range of the graph from any mixture of sulphur dioxide and oxygen and any unreactive gases. A useful form of the equili-

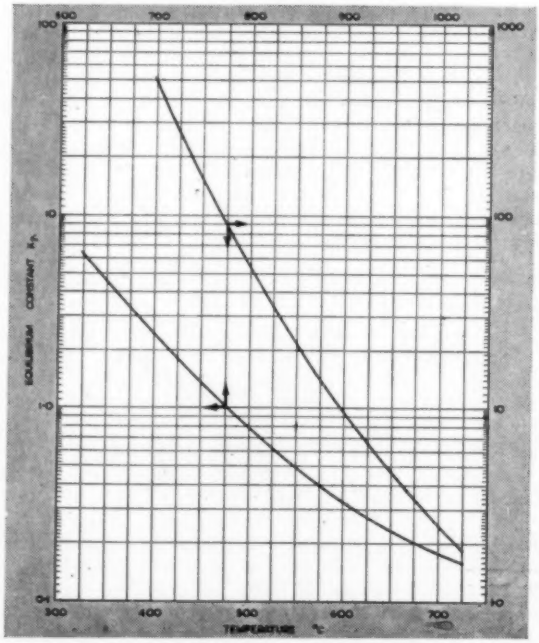

Fig. 1. Equilibrium constant for reaction.

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brium equation for such calculations can be derived as follows.

In the reaction let there be a unit number of molecules, b, of which oxygen and c are unreactive gases and let x molecules of SO_3 be formed from this mixture. Then the molecular equation becomes:

	SO_2	+	$\frac{1}{2}O_2$	$\leftrightharpoons$	SO_3
Mols.	$1-(x+b+c)$		$\left(b-\frac{x}{2}\right)$		x

Since the partial pressures are proportional to the number of molecules, we can express the appropriate partial pressures as the following fractions of the total pressure P, bearing in mind the c molecules of unreactive gases.

For SO_2 $$\frac{[1-(x+b+c)]\,.\,P}{(1-x/2)}$$

for O_2 $$P\,(b-x/2)\,/\,(1-x/2)$$

for SO_3 $$Px\,/\,(1-x/2)$$

Thus $$K_p = \frac{x\,[1-x/2]^{\frac{1}{2}}}{[1-(x+b+c)]\,[b-x/2]^{\frac{1}{2}}.\,P^{\frac{1}{2}}}$$

or $$K_p = \frac{x}{[1-(x+b+c)]}\left[\frac{1-\frac{x}{2}}{\left(b-\frac{x}{2}\right)P}\right]^{\frac{1}{2}} \quad \ldots . (4)$$

From Fig. 1 at the chosen temperature, K_p can be read and x can be determined from the above equation by trial substitution, graphing the results and interpolating at the appropriate value of K_p.

Usually the diluents of sulphur dioxide entering the converter are nitrogen remaining from air used in the combustion of the sulphur-bearing materials and excess air. Air is, of course, the usual source of oxygen in the burning and conversion stages and all subsequent considerations in this article will be based upon this source of oxygen. We shall also mainly concern ourselves with sulphur as the raw material for SO_2, although we shall make some few references to iron pyrites.

In the sulphur process the formation of sulphur dioxide is in accordance with the following equation:

$$S + O_2 = SO_2 + 70{,}900 \text{ cal.}$$

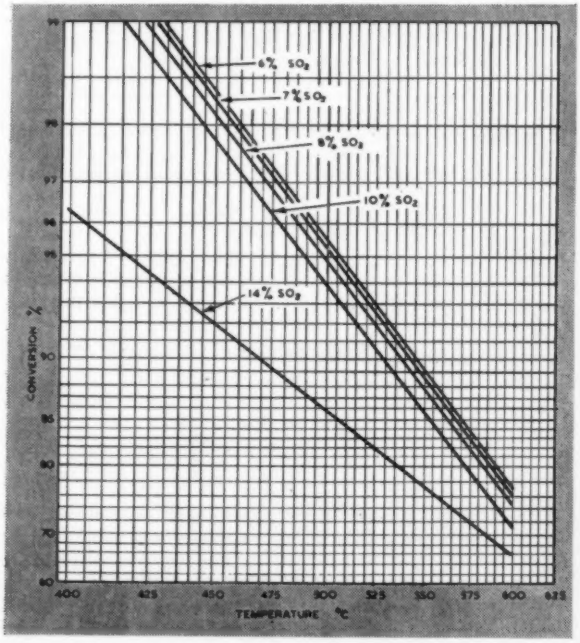

Fig. 2. Theoretical conversion of sulphur gas.

Since one molecule of sulphur dioxide is produced from one molecule of oxygen the richest sulphur-dioxide gas obtainable from air is that in which all the oxygen in the air has been replaced by an equivalent number of molecules of sulphur dioxide; that is to say, a concentration of 21% of sulphur dioxide by volume. Lower concentrations depend upon the quantity of excess air used or upon the presence of combustible materials in the sulphur-burning material which consume oxygen without producing sulphur dioxide.

For pyrites of composition FeS_2 the equation for burning is:

$$2\,FeS_2 + 5\tfrac{1}{2}O_2 = Fe_2O_3 + 4SO_2 + 411{,}180 \text{ cal.}$$

which gives a maximum concentration of 13.2% SO_2.

From the equilibrium equation it is clear that the conversion of sulphur dioxide to sulphur trioxide is favoured by the degree of concentration of oxygen in the gas mixture, and for this reason where pure oxygen is available as a waste material from another process it is fed to the burner with air. The degree of conversion for both sulphur and pyrites from gas of various initial concentrations of SO_2 are shown in Figs. 2 and 3. The reason why there are different conversions for gases of sulphur and pyrites origin is, of course, due to the fact that in the preparation of sulphur dioxide from pyrites oxygen has been consumed to make iron oxide, leaving more unreactive nitrogen than in the case of sulphur dioxide of sulphur origin. The unreactive gases act as diluents of the sulphur dioxide with a consequent reduction of mass action.

If pure oxygen were used higher conversions would be obtained and any differences in the conversions obtained from sulphur and from pyrites would be solely due to the difference in the partial pressures of the remaining oxygen. It is clear from these graphs that the more the sulphur dioxide is diluted with air (more oxygen) the higher is the conversion at equilibrium. This is the result of the double effect of mass action and of the smaller rise in temperature of the gas mixture consequent upon the heat of reaction from sulphur trioxide produced being dissipated in more diluting gas.

From Figs. 2 and 3, the lower the equilibrium temperature the higher is the conversion. There is, however, a limit to this dilution, unless the gas is to be preheated prior to the conversion stage. As will be explained in a later section on the kinetics of the reaction, the catalyst has a minimum biting temperature below which it has no effect. Therefore, in the burning process, if there is more than a certain maximum quantity of dilution air, the temperature of the gas from the burner will be lower than this minimum. The maximum temperatures of gases over a range of dilutions of both sulphur and pyrites origin are shown in Fig. 4. These have been calculated from the specific heat expressions:

$$SO_2 : 8.12 + 0.006\,825T - 0.000\,002\,103T^2$$
$$O_2 : 6.13 + 0.002\,99T - 0.000\,000\,806T^2$$
$$N_2 : 6.30 + 0.001\,819T - 0.000\,000\,345T^2$$

and for iron oxide produced in the pyrites process

$$Fe_2O_3 : 24.72 + 0.01604T - \frac{423400}{T^2}$$

in which T is the absolute temperature.

These have been integrated between limits T_1 and T_2 so that they are of the form

$$a(T_1 - T_2) + \frac{b}{2}(T_1^2 - T_2^2) - \frac{c}{3}(T_1^3 - T_2^3)$$

except in the case of Fe_2O_3 which takes the form

$$m(T_1 - T_2) + \frac{n}{2}(T_1^2 - T_2^2) + p\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$$

a, b, c, m, n and p being of course the constants in the above equations. Since the lower temperature T_2 is known and is the atmospheric temperature (288°K), by multiplying these molal heats by the number of molecules participating and equating

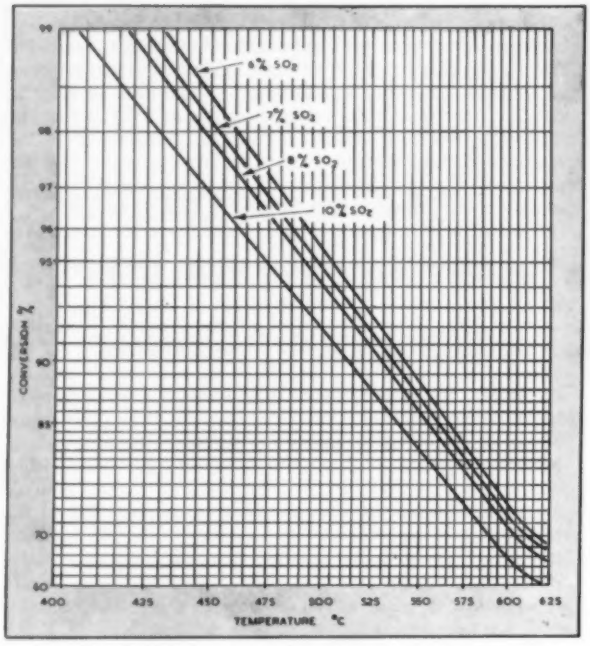

Fig. 3. Theoretical conversion of pyrites gas.

the sum of this heat with the heat of reaction, T_1 can be found graphically. The results obtained are shown below.

Sulphur Gas Temperatures

% SO_2	3.5	5.25	10.5	21.0
Temperature, °C ...	358	515	952	1702

Pyrites Gas Temperatures

% SO_2	3.85	7.7	11.55	15.4
Temperature, °C ...	527	940	1282	1577

From these graphs it is seen that for a biting temperature of 415°C the minimum concentration of SO_2 from sulphur which can be used is 4.0%. For pyrites the corresponding figure is seen to be 3.1%; but this is largely only of theoretical interest, since pyrites gases invariably have to be cooled after the burner stage in a purification process and are subsequently reheated using the exothermic heat from the conversion stage. A similar process of utilising the heat of conversion is, of course, available for preheating weaker gases from sulphur.

The temperature of the gases fed to the converter are controlled as near the biting temperature as possible, since the lower the temperature the higher the equilibrium conversion. Then as conversion takes place in accordance with Equation (1) heat is released and the gas mixture rises in temperature in accordance with the appropriate specific heats, the equations for which are given above for sulphur dioxide, oxygen and nitrogen, while for SO_3 the equation is:

$$8.20 + 0.010\,236T - 0.000\,003\,156T^2$$

The temperature can rise until the equilibrium conversion is achieved. The progress of this temperature is shown in Fig. 5. These conversions and the corresponding adiabatic temperatures are shown in the following table for initial gas strengths of 14, 10, 8, 7 and 6% SO_2 initially at 415°C.

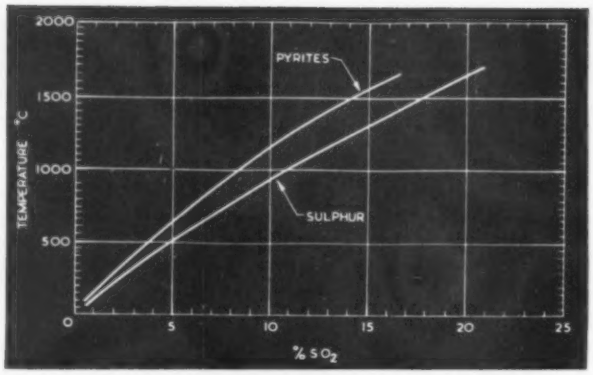

Fig. 4. Maximum temperature of gases leaving burner.

% SO_2	14	10	8	7	6	
Adiabatic Temp., °C	636	610	593	580	567	First stage
% Conversion ...	54.0	67.8	76.1	81.6	86.0	

It is not possible to obtain further conversion with these gases unless they are cooled, and it is therefore common practice to introduce two, three or four stages in the converter, the gases being cooled between stages to the biting temperature of the catalyst. This is also shown in Fig. 5 for a four-stage converter with an initial 8% SO_2 gas. The adiabatic temperatures and conversions corresponding with each of the above gas strengths are shown for the second, third and fourth stages with interstage cooling to 415°C before the next stage.

% SO_2	14	10	8	7	6	
Adiabatic Temp., °C	528	493	465	450	437	Second stage
% Conversion ...	81.7	94.8	97.4	98.2	98.8	
Adiabatic Temp., °C	455	426	417	417.5	416.3	Third stage
% Conversion ...	91.4	96.5	99.1	99.3	99.4	
Adiabatic Temp., °C	426	422	415	415	415	Fourth stage
% Conversion ...	94.3	98.8	99.2	99.3	99.4	

It must be emphasised that these are equilibrium conversions and also that they correspond to adiabatic temperatures; in other words, they take no account of possible heat losses.

Effect of Pressure on Conversion

The equilibrium Equation (4) applies only to pressures in which the activity of the substances can be taken to be identical to the partial pressure of the gas. At higher pressures this equation has to be modified to include a constant $K\gamma$ or fugacity coefficient, so that Equation (4) correctly reads:

$$K_P = K_\gamma\left[\frac{x}{1-(x+b+c)}\right]\left[\frac{\left(1-\frac{x}{2}\right)}{\left(b-\frac{x}{2}\right)P}\right]^{\frac{1}{2}}$$

Values of these coefficients for various pressures and temperatures are given in Fig. 6. In accordance with Le Chatelier's principle, since its formation is accompanied by a reduction in pressure, an increase in pressure favours the formation of sulphur trioxide. Thus with a 7.8% SO_2 pyrites gas at 600°C and 1 atm, the conversion is 80%, whereas at the same temperature but with a pressure at 100 atm the conversion is 98%.

Gas Concentration and Pressure: Influence on Design

From the above it is seen that at equilibrium the maximum conversion occurs at the lowest temperature with the lowest gas concentration and at the highest pressure. But in practice the initial plant cost and running costs need to be considered. As low gas concentrations mean large vessels and ducts, and high pressures need thick-walled vessels, up to the present time such additional expense cannot be justified. A further disadvantage to dilute gases is that since their temperature from the burner is by comparison low, there is a low-temperature differential in the heat exchanger and the recovery heat is more expensive. The gas temperature is determined by the biting temperature of the catalyst and consideration must also be given to the maximum temperature the catalyst will tolerate without decomposition or disintegration.

Quenching

Above it was suggested that a possible method of avoiding the disadvantages of dilute gases from the burner and yet secure the advantages of dilute gases to the converter would be to make concentrated gases in the burner and dilute them down just prior to the conversion stages. In this way the advantages of both strong and weak gases are obtained in the same plant. A strong gas produced in the burner has a high temperature giving good heat exchange at the waste-heat boiler and allows small vessels and ducting. If this gas is diluted at appropriate stages in the converter with cold air the effect is one of cooling the gases and also of diluting them both of which improve conversion.

In Fig. 7 the effect of successively diluting a 14% gas of sulphur origin is shown. From this diagram it is possible to determine the equilibrium conditions obtained from diluting such a gas so that it corresponds to gases of original SO_2 concentrations of 14, 10, 8, 7 and 6%.

Velocity of Reaction

All of the above considerations were based upon equilibrium being achieved. The speed at which the reaction proceeds to equilibrium will now be discussed. It is hardly necessary to emphasise that the velocity of the reaction is one of very great practical concern. The velocity of this reaction is highly sensitive to the presence of catalysts. We have not been able to discover in the literature the extent of this reaction in the absence of catalysts because the number of substances which act as catalysts are very extensive; even glass has an influence. Norrish and Rideal report, however, that it is not until 305°C that measurable quantities of SO_3 are produced—but this determination was made in glass vessels.

The selection of a catalyst is mainly empirical and many metals and metallic oxides were tried, but up to the present time the only two elements adopted industrially to effect oxidation of SO_2 rapidly at temperatures below 500°C have been platinum and vanadium. Iron oxide was used in the Mannheim process, but this material is relatively inactive at temperatures below 600°C and at this temperature the maximum theoretical conversion that can be achieved is 60% and it was therefore necessary to have a second conversion stage. In this case platinum was used.

From the literature it is interesting to note that the catalytic effect of palladium and iridium is low compared with platinum. A comparison using in each case 10 grams of mass containing 1.5% of the metal and passing a gas mixture of 1 part SO_2 and 2.5 parts air at the same rate of flow shows the following:

Comparison of Catalytic Conversion

Temperature, °C	Percentage conversion when using catalysts		
	Platinum	Iridium	Palladium
450	96.2	27.0	0.5
500	89.5	56.7	9.8
550	79.9	67.1	23.4
600	68.8	60.0	27.2
650	47.9	42.8	40.0

The success of a catalyst apart from the advantages of a low kindling temperature is dependent upon the nature of the carrier used. This vehicle must be porous in order to present the greatest possible surface to the gases. It must be capable of withstanding high temperatures and be inert to sulphurous gases. In the case of platinum it must be capable of treatment for recovery of the platinum. These considerations have restricted materials that can be used. Those which have proved successful are asbestos fibre, magnesium sulphate, silica gel and kieselguhr. The first two are used for platinum and the latter two for vanadium.

The common method of making the platinum catalyst was to soak the asbestos in, say, platinum chloride solution; to remove the platinised asbestos, allow it to drain, dry, and fluff it out. Due to the lightness of this catalyst mass it was necessary for the converters to be down-draughted. The platinised magnesium sulphate mass which was generally used in the Grillo Schroeder process was prepared by spraying

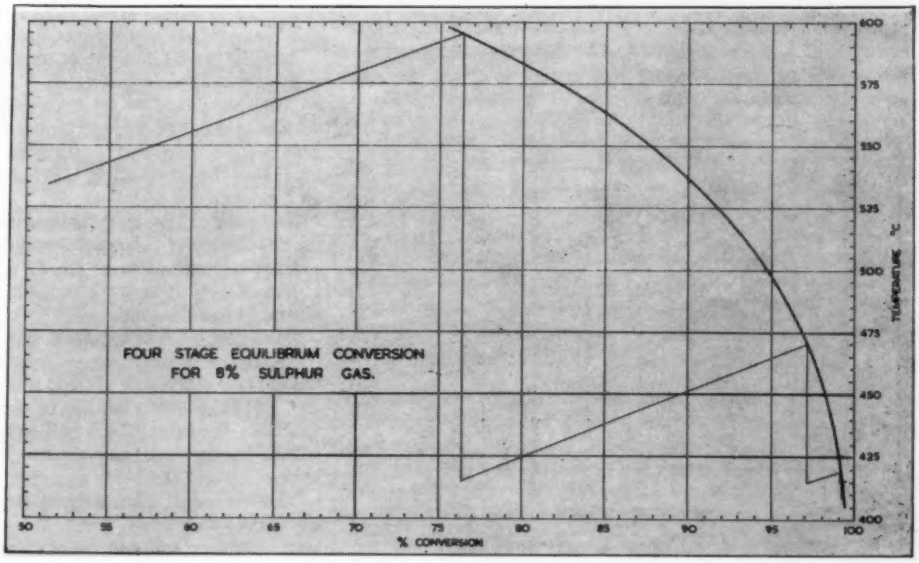

Fig. 5. Maximum temperature of gases over a range of dilutions of both sulphur and pyrites origin.

platinic chloride on to calcined magnesium sulphate. The platinum content of the mass was approximately 0.3%. Platinised silica gel, which was considered much more durable material than either of the other two due to the carrier being harder, consisted of a gel prepared from sodium silicate and hydrochloric acid; this material was then dried and sprayed with ammonium chloro-platinate.

In the early designs of converters the platinum loading was approximately 10 oz. a ton of acid a day, but improved converter design resulted in this being reduced to approximately 4 oz. of platinum a ton a day.

Although vanadium was advocated for use as a catalyst as early as 1900 it was not until 1915 that it was used on a commercial scale, but this early use was apparently unsuccessful due to the disintegration of the carrier causing a high pressure drop across the converter. Vanadium pentoxide itself is a comparatively poor catalyst and it is only when so-called activators are added that high conversions can be achieved. It is therefore normally compounded with an inert substance of very large superficial area such as kieselguhr. Manufacturers usually specify very carefully the type of carrier used. A representative specification for kieselguhr is that the density must lie within the range of 130/150 grams a litre and that it must be sufficiently porous to take up 300/320 grams of water at room temperature without flowing easily.

These activated catalysts fall into a class of composition:

$$xM_2O,\ yV_2O_5,\ zSO_3.$$

The metal M in the above formula is usually potassium, sodium being comparatively poor (one authority says it has not more than 60% of the activity of a potassium catalyst) while rubidium, cæsium and thallium are successively, and in that order, improvements on potassium.

There is no doubt that a substance of the above general composition is molten at normal conversion temperatures. Topsøe and Nielsen state that the function of these metals is to provide solvents for the vanadium so that a free-flowing liquid is produced at the temperature of the reaction. In support of this argument they state that only those metals act as activators which (a) produce low melting point pyro-sulphates, (b) have the ability to absorb SO_3 to decrease their melting point even lower and (c) produce melts of low viscosity. They state that this is further supported by the fact that the catalyst when made is not active until it has been heated in a stream of SO_3 so that pyro-sulphates can be produced. They state that the catalyst functions in the liquid flowing over the surface of the carrier. They have shown that it is possible to obtain similar conversions to those of a conventional catalyst by using a molten catalyst without the carrier circulating this over a packed tower. They claim that this method could form a practical process. The same investigators have made up pellets containing catalyst in an outside annulus and only the carrier in the central core. They have shown that after a very short time the pellet becomes homogeneous.

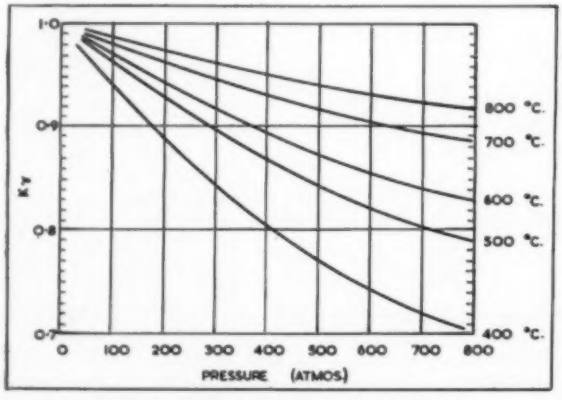

Fig. 6. Ratio of fugacity coefficients.

The ratio of M_2O/V_2O_5—usually K_2O/V_2O_5—is found to be important in conferring activity on the catalyst. The higher this ratio the lower the biting temperature of the catalyst. The I.C.I., in a patent, state that the following compositions will give optimum velocities at the temperatures indicated:

Optimum Compositions at Various Temperatures

Temp. ...	380	390	400	410	420	430	440	450	460	470
K_2O/V_2O_5 Ratio	5.4	5.0	4.5	3.9	3.3	3.1	3.06	3.04	3.03	3.02

The patentees suggest that the catalyst bed could be made up in successive layers of the above compositions so as to get maximum reaction speed as the conversion proceeds.

Typical compositions of vanadium catalyst in commercial use are as follows:

V_2O_5	K_2O	Carrier
9.0%	10.4%	70% silica kieselguhr or cellite
6.0%	8.0%	
9.5%	10.0%	
7.1%	9.8%	
8.6%	9.7%	

Iron and manganese are said to improve the activity of the catalyst, but Topsøe and Nielsen say that if this is present to a greater extent than 15% to 20% of the molar vanadium present the activity falls off.

Typical methods of preparing the catalyst mass are as follows: 80/90% vanadic acid containing 12.6 kilos of V_2O_5 is placed in a vessel and made damp with water, 37.4 kilos of 50% caustic potash are added and the mixture warmed in order to dissolve the V_2O_5. When the solids are dissolved, the solution is neutralised by the addition of 16 Be. sulphuric acid until a test sample turns litmus weakly blue. The contents are then made up to 90 litres total volume by the addition of water and 120 kilos of kieselguhr and 18 kilos of sulphur are added. The vanadic-acid suspension is quickly added, followed by 5 to 6 litres of 5% ammonia liquor, and the whole mass mixed for 15 minutes. This mass is then extruded and calcined at a temperature of approximately 800°C.

Another method given is to use a vanadium compound, such as vanadium oxychloride ($VOCl_3$), vanadium oxalate or ammonium vanadate to which has been added potassium silicate. Then 10% sulphuric acid is added to this mixture so that the *pH* is below 4, otherwise the silica gel produced is unstable. The whole mass is dried without filtration, calcined and ground.

It is necessary for all vanadium masses to be activated before use. The catalyst is heated slowly with hot air until the mass reaches a temperature of 450°C, then a 2% SO_3 gas mixture is passed over it and the temperature raised to 500°C. The mass can then be used.

Poisoning of these catalysts appears to be of two kinds:

(a) That in which the catalyst recovers activity as soon as the poison is removed from the gas stream.

(b) That which cannot be removed except by chemical action; for example, by boiling in sulphuric acid.

The former type of poisoning is known as reversible or temporary and the other as irreversible or permanent.

The degree of poisoning is measured by the relative reduction of the velocity constant by a unit weight of poison on unit weight or unit volume of catalyst. Let this be α

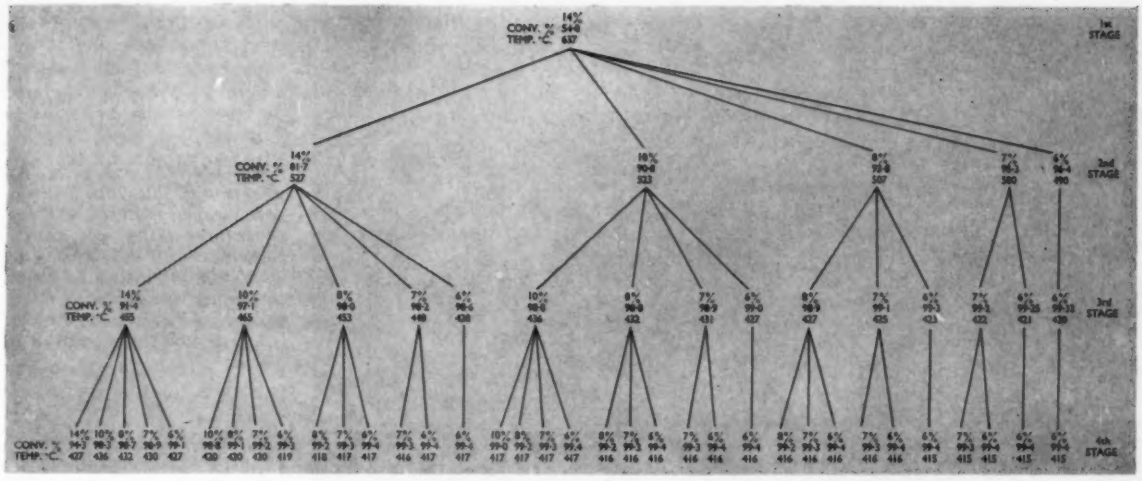

Fig. 7. Stages in quenching 14% SO_2 sulphur gas. Initial temperature 415°C.

$$\text{Then } \alpha = \frac{-dK}{K\,dg.}$$

Where K = velocity constant and
g = weight of poison.

$$\text{Whence } \alpha\, dg = \frac{-dK}{K}$$

and integration gives $\alpha g = \log_e k + c$

$$\text{or } \alpha = \frac{2.303}{g} \log_{10} \frac{K_1}{K_2}$$

where K_1 and K_2 are the limiting values of the velocity constants over the range considered.

Values of α which have been established are:

As_2O_3 on platinum at 450°C $\alpha = 61$ / gram of catalyst.
As_2O_3 on platinum at 500°C $\alpha = 32$ / gram of catalyst.
As_2O_3 on Ba–Sn–V_2O_5 $\alpha = 0.01$ / litre of catalyst.
As_2O_3 on $K_2O - V_2O_5$ $\alpha \simeq 0.01$ / litre of catalyst.

It has been stated that the effect on the vanadium catalyst below 550°C reaches a maximum and does not increase with more poison. At temperatures greater than 550°C a volatile compound of As_2O_5 and V_2O_5 is formed which condenses in subsequent catalyst layers.

The following example illustrates the effect of arsenic upon the activity of a vanadium catalyst.

It is required to find the time for the activity of a vanadium catalyst to be reduced to half its initial value given the following:

(a) Arsenic content of the pyrites is 0.1%, and 75% of this is volatilised into the SO_2 gas stream.
(b) One ton of pyrites contains 0.50 ton sulphur and therefore yields 1.53 tons sulphuric acid.
(c) One ton of acid per day requires 200 litres of catalyst.

The quantity of arsenic volatilised from 1 ton of pyrites is 0.000 75 ton of arsenic, or 761 g. Hence 1 ton of acid will contain $\frac{1}{1.53} \times 761 = 497$ g. of arsenic.

The time taken is then calculated as follows:

$$\frac{K_1}{K_2} = 2$$

but $\alpha = 0.01$

$$\text{then } \alpha = \frac{2.303}{g} \log_{10} \left(\frac{K_1}{K_2}\right)$$

$$\text{or } 0.01 = \frac{2.303}{g} \log_{10} 2 = \frac{2.303 \times 0.3010}{g}$$

$$\text{and } g = \frac{2.303 \times 0.3010}{0.01} = 69.4 \text{ grammes/litre of catalyst.}$$

This quantity of poison will reduce the activity of the catalyst to one-half its original value. This will happen after

$$\frac{69.4 \times 200}{497} = 27.9 \text{ days.}$$

The effect shown in this calculation is, in practice, much enhanced because the initial layers of catalyst in the first pass are first out of order. Therefore the initial stages of conversion are not so far advanced as was allowed in the design, and the additional duty of conversion is thrown upon subsequent stages in the converter for which cooling facilities have not been provided. The system is therefore thrown completely out of balance with considerable decreased efficiencies. This is why elaborate gas purification systems are used when producing sulphuric acid from arsenical ores.

Both tellurium and selenium poison platinum. Selenium is said to affect vanadium pentoxide at temperatures less than 400°C only and the catalyst recovers its activity by heating at 480/500°. The effect of tellurium on vanadium is unknown.

Carbon monoxide has a deleterious effect upon the reaction in the case of vanadium catalyst, because vanadium catalyst, unlike platinum, does not oxidise carbon monoxide to carbon dioxide and the carbon monoxide reduces the sulphur trioxide formed. Carbon or soot affects both platinum and vanadium because it in fact obscures the surface.

Hydrogen sulphide does not affect platinum adversely and with vanadium catalysts satisfactory runs of over 100 hours have been obtained at 480°C and 425°C with gases containing 3% H_2S. However, in the wet catalyst process for oxidising H_2S directly to SO_2 and water in the burner, if a gas of this composition is passed for several hours and then exchanged for a gas of sulphur origin, the catalyst activity is depressed. The activity can be restored by heating the catalyst above 500°C. Chlorine and hydrochloric acid gas poison platinum severely and reversibly, but they have no effect upon vanadium.

Silicon tetrafluoride has a bad effect on platinum due to the formation of silica on the catalyst. It is also said to be harmful to V_2O_5, though whether this is due to the effect on the carrier or upon the catalyst itself has not been stated.

There is an effect which is analogous to temporary poisoning resulting from the use of gases at too low a temperature. The presence of SO_2 at temperatures below 420°C has the effect of reducing the V_2O_5 to V_2O_4 and even to V_2O_3, and thereby reducing the activity of the mass. However, this situation can be rectified with the catalyst *in situ* by blowing through with hot, dry air at 480/500°C, thereby reactivating the mass.

Fig. 1. Heated roller sieving screen with individual rollers and scraper plates heated to prevent sticking of damp, brown coal on the roller. The heating connections are on the near side and the mechanical drive on the far side of the screen.

CHEMICAL PLANT AT LEIPZIG TRADE FAIR, 1958

THE Spring Leipziger Messe comprised a sample fair and a technical fair. In 1958 the latter covered almost 6,000,000 sq. ft. and consisted of 40 halls and pavilions as well as a big open-air exhibition. Roughly one-third of the space was taken by West German and foreign firms, including a small group of British exhibitors. Among the 30 trade groups were several making equipment of interest to the chemical processing and allied industries. In some cases these represented new developments; in others, products were exhibited because they had never previously been made in East Germany. Some of the more notable East German exhibits are described below.

HEATED FINE-SIEVE ROLLER SCREEN

For sieving fine, damp, sticky material, such as brown coal, the Veb Eisengiesserei und Maschinenfabrik Zemag Zeitz have developed a heated fine-sieving machine. In its original form this machine consisted of a row of finned rollers—alternate rollers rotating in opposite directions—the fines falling between the rollers. Sticky materials often caused difficulties with this machine and, to overcome these, the present model was developed. Both the scraper plates underneath the rollers and the rollers themselves are internally steam heated in order to prevent sticking of the particles of coal and building up of deposits. This also minimises frictional wear on the rollers. The steam heating is completely separated from the driving mechanism and can be individually adjusted for each roller, as can be seen in the accompanying photograph. The whole of the drive is on the opposite side of the sieving grate from the steam connections. Despite the heating arrangements, it is said that all parts liable to wear can be readily replaced. Individual rollers can be dismantled and fitted without disturbing the oil-tight housing for the drive. The sieve is available in sizes up to 1½ m × 6.93 m for throughputs up to and over 100 tons an hour and apertures ranging from 0 to 10 mm.

HYDRAULIC CONTINUOUS BAND WEIGHING MACHINE

A new hydraulic continuous band weighing machine has been developed by Veb Zementanlagenbau Dessau, which includes a control that can be set to switch off the feed after any particular aggregate weight has been delivered. These machines range up to capacities of 8 to 40 tons an hour and are driven by a motor taking 300 W. With an overall length of 1.75 m, they weigh about 250 kg. They can weigh any non-sticky material such as cement, clinker, coal or chalk, indicating both the hourly quantity on the band at any moment and the aggregate weight from the last setting. The indicators can be connected for remote indication and the accuracy is given as ±2%.

BRIQUETTING EXTRUSION PRESS

For materials that are briquetted with difficulty as well as for the manufacture of fine-grain briquettes for the production of coke, the simple sliding-crank press is often unsatisfactory. A machine designed to overcome these difficulties is the so-called toggle-lever press, having almost the same component parts as the sliding-crank presses but with a different action. In order to improve the pressing process, a toggle-lever gearing is fitted between the crankshaft and the rams in order to lengthen the period of both the forward movement and the residence at the point of maximum pressure. Compared to a simple sliding-crank press of equal rate of revolution, the toggle-lever press is reported to yield stronger briquettes. This is of particular advantage for coke-making from East German coal. Furthermore,

by means of the toggle-lever press, it is possible to make useful briquettes out of materials that otherwise are hard to briquette with the simple sliding-crank press. Toggle-lever presses were offered constructed for electric and steam drive. A twin press of 2 × 10 in. with electric drive designed to use a stroke of 220 mm for lignite briquetting, or about 300 mm for peat briquetting due to the lower weight of peat, was exhibited by Veb Schwermaschinenbau Georgij Dimitroff.

PROGRAMME-CONTROLLED CENTRIFUGE

A new development shown by the Veb Maschinenfabrik Sangerhausen was a programme-controlled white sugar centrifuge—a modification of their previously-offered suspended centrifuge. The drum has a diameter of 1.25 m and can take a load of 500 kg. It has an output of 10 to 15 charges an hour and can be operated at three speeds—namely, 225, 485 and 960 rpm. The control gear is so arranged that the centrifuge can be controlled by hand or automatically. Thus each charge can be worked either individually or continuously. In the latter case, the centrifuge runs continuously, switching itself on and off and filling and emptying itself. The complete working sequence involves fully-automatic operation of the scraper, the cover, the brake, the syrup separation and the steam and water covering. Plans for 1958 include the extension of the range to include capacities up to 650 kg and speeds up to 1450 rpm and improvements in the control mechanism.

GAS-MOTOR PISTON COMPRESSOR

The main application intended for the new gas-motor piston compressor exhibited by Veb Maschinenfabrik und Eisengiesserei Wurzen is in pumping stations for conveying methane gas in long pipelines. A further important application will be in oilfields. In the latter case these machines are used for conveying petroleum using a gas lift. They have been made as light as possible to improve mobility and can be transported without dismantling. The gas-motor compressor consists of a powerful four-stroke motor in V form and a horizontal double-acting piston compressor with cross-head guide. Both machines are linked into one unit and work on a common crankshaft. This produces a very compact construction which gives very good balance of the masses and is relatively light in weight. The intermediate cooler can be arranged, if required, directly on the compressor portion above the cylinder. It is intended for work not only in the oilfields, but wherever gas is available as a fuel. The compressor can be used for air or other gases. The machine is normally constructed in four sizes of unit up to an eight-cylinder type of 200 hp with four compressor cylinders. All models are built in standard interchangeable units, reducing the number of spares required.

HAMMER CRUSHER

A new hammer crusher was shown consisting of a strong sheet-metal housing of welded construction which was divided in the plane of the machine shaft and provided with impact plates in the interior made of wear-resistant steel. The side walls of the housing are similarly protected with wear plates. The striking roller is equipped with easily-changeable striker arms. For good accessibility, the interior of the housing and particularly the striker arms are provided with inspection shutters with a rapid locking device. The machine is driven by an electric motor with a V belt and is designed for reducing clinker from a rotary kiln to a size of 0 to 30 mm, 70% of the product being below 10 mm. It is said to be equally suitable for crushing medium-hard stones such as chalk, coal, slate and similar materials. The very simple construction of the machine is thought to give it particularly great advantage in comparison with other crushing machines, since it has only a small number of parts liable to wear. The wear is given as between 8 and 25 g per ton, dependent on the material being crushed. Machines available range up to one having a throughput of 40 tons of rotary kiln clinker of maximum size (200 mm) and a power consumption of 36 kW. This was also supplied by Veb Zementanlagenbau, Dessau.

FILTERS

Filter presses were exhibited which had been designed for dewatering mixtures for porcelain and stoneware manufacture, kaolin, dyes and similar products. Two novel features were the use of circular plates and of hydraulic locking of the filter press. The filter plates are carried in the usual way on two supporting rods between a fixed end

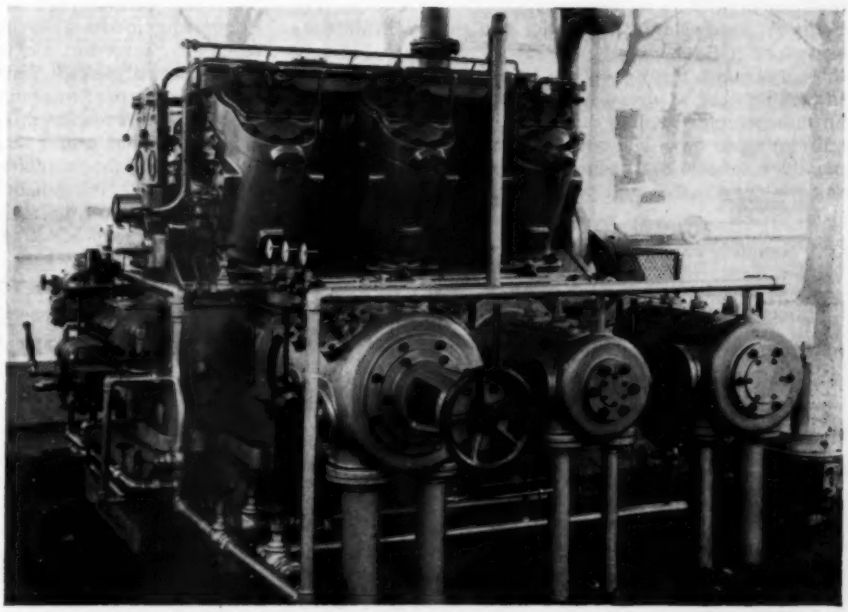

Fig. 2. Compressor driven by natural-gas motor. This six-cylinder engine is driving a three-stage gas compressor on common crankshaft. The compressor is particularly intended for use in oilfields.

and movable head, but the latter could be locked either manually or by a hydraulic device. It is claimed that the round shape adopted for this design has an advantage over the usual square-shaped press, since there is a more even pressure distribution over the whole filter surface and, therefore, a uniform thickness of filter cake. The shape is also claimed to give a more secure sealing of the individual chambers by the rubber ring packings and also to aid in the cleaning of the filter cloths. This unit was exhibited by Veb Thuringia Feinkeramikmaschinen Sonneberg.

A newly-developed steel filter press of 800-mm section was exhibited by Veb Maschinenfabrik Halle as being specially designed for the oil and sugar industry. The press is equipped with plates and frames of part plastic construction intended to avoid corrosion, to give a high filtration output and a favourable runaway of filtrate. It is sealed by electric control operated by push button. A further filter device was a clothless ceramic candle pressure filter for the soda, dyestuffs, potash and sugar industries. This is intended particularly for filtration of slimes of all kinds by the replacement of filter cloths with durable filter media of porous, stiff, synthetic material. In the pressure filters, filter-rings are used which are made of different material according to the liquid to be filtered. These materials included fitted quartz, glass, fireclay, kieselguhr or coal. The filters are offered in sizes with filter surfaces of 5, 16, 28, 39 and 52 sq. m area, with corresponding diameters of 0.5 to 1.6 m and a height of 4 m. The operating pressure is 6 or 8 atmospheres. Suppliers are Veb Maschinen und Apparatebau Stassfurt. A further filter press exhibited—this time by Veb Maschinenfabrik Halle—is claimed to give 100% higher output than comparable units, although the precise reasons for this are not clear. The filter press in question is the NCh viscose frame filter press which is 470 mm. square. The welded construction of the filter cases increased the resistance to fracture compared with cast plates.

TURBO CUTTER MACHINE

Among the units specially developed for the equipment of sugar factories was the turbo cutter machine shown by Veb Maschinenfabrik Sangerhausen. This machine was guaranteed to give an output of 1500 tons per day of finely shredded beetroot. It consists of a stationary drum 1.4 m in diameter with 16 recesses which take a knife-drum. The beetroots are fed into the interior and thrown against the knives by a three-bladed rotor at speeds up to 115 rpm; the cuttings are thrown outside the stationary drum. With the addition of a supply hopper for the beetroot to give an uninterrupted supply, the output was guaranteed to be 1500 tons per day. The new machine was claimed to be readily accessible for maintenance and to yield a product suitable for the diffusion process.

MOBILE OXYGEN PLANT

A complete mobile oxygen production plant on a trailer yielding 8 cu. m an hour of 99.5% oxygen was shown by Veb Maschinenfabrik und Eisengiesserei Wurzen. The power supply can be obtained either from the mains or by means of a mobile generator. The complete plant consists of a three-stage air-cooled dry compressor giving up to 60 atmospheres and is driven by an electric motor. CO_2 is absorbed under pressure in KOH or NaOH solution and the air dried using silica gel, which can be regenerated *in situ*. The main air separation apparatus is equipped with heat exchangers and a one-stage rectification column in an insulated metal housing. There is a single-stage standing-expansion machine with carbon ring packings in the cylinder and controlled valves, together with a piston pump for compression of the liquid oxygen to a maximum of 150 atmospheres. The filling equipment has three outlet connections. Thus the air intake is filtered, compressed to a steady pressure of 40 atmospheres, washed free of CO_2, dried, then cooled in counter-current at the entry to the air separation apparatus. One part is then expanded in the expansion machine to cover the cold requirements and the remainder through a throttle valve. The rectification column is arranged as a driving column. The pressure in the vaporisation coil was 4 atmospheres and in the column about 0.4 atmospheres. The liquid oxygen obtained is compressed by the piston pump to a maximum of 150 atmospheres. The liquid is then gasified in the heat exchanger and the final containers are filled at 20°C.

HIGH-PRESSURE ACETYLENE PLANT

Although generating plants have been available for roughly 40 years for large-scale users of acetylene, the recent models exhibited were claimed to have a number of advantages over all earlier developments. The gas lock arrangements were greatly improved, so that charging with carbide and removal of solid residue could be carried out without interruption of production. Charging with carbide was now said to be completely dust-free and the purging of the carbide feed during the operation so controlled that the gas and air mixture released is harmlessly blown out on top of the roof. The previous disadvantages in charging acetylene gas producers—namely, the serious production of dust and the risks caused by the release of a gas-air mixture in the service room—have been overcome with this plant. The generator can use carbide particles sized between 4 and 80 mm, either graded or mixed. They are gasified on a rotating grate. The generator is controlled by the demand for gas, but, in addition, for the first time also by the operating temperature to promote economy and safety in operation. This plant was offered by Veb Maschinenfabrik und Eisengiesserei Wurzen. With an output of 75 m^3/hr, the carbide filling was 300 kg., operating pressure 0.1 to 1 atmosphere with stepwise regulation but capable of operating up to 1.5 atmospheres, and weight 3½ tons.

NEW MEASURING GEAR SYSTEM

The VEB Geräte und Reg'er-Werke Teltow announced that they had recently developed a measuring gear system which they called the Kombi System. They exhibited regulating equipment based on pneumatic or mixed pneumatic controls and constructed out of unit elements. Equipment included rapid transfer apparatus, pressure regulators, inversion elements, impulse mixing elements, remote-control elements, and so on, permitting the assembly of various types of transmitters and regulators for pressure, pressure difference, level, temperature, temperature difference and similar properties. The equipment appeared to be conventional—the exhibitors themselves admitting that leading British instrument manufacturers were ahead of their designs—and the main interest lay in the fact that it represented the product of a new industry.

CORRECTION TO FEBRUARY ISSUE

IN THE ARTICLE on "Coal Research", February 1958 issue, page 84, paragraph 4, lines 9 to 17 shou!d read:

"After noting that the combined water and tar acid yield is in good agreement with that expected from the hydroxyl contents of coal, Dryden made the suggestion that it may be possible to increase the tar acid yie'ds many times at the expense of water if methods can be found. There is also apparently a margin on stoichiometric grounds for increasing the yield of tar to a theoretical figure of about 140 gallons a ton, but unless the mechanisms of decomposition can be radically changed, the theoretical maximum may be only about a third of this figure. Industrial yields of gas are close to those stoichiometrically possible."

A.B.C.M.'S ADVISORY SERVICE

THE problem of selecting the right piece of ancillary equipment for a chemical plant and of installing it correctly is a frequently recurring one. It arises at the final stages of a project when the equipment shown on the flow sheet is being specified in detail. On occasions when replacements are called for at already commissioned plants, or when components have shown themselves unsatisfactory, the problem will arise anew. The scope of the same projects may be so great that the experience necessary for selecting and installing correctly many of its ancillary items of equipment may not be possessed by its designers. In such cases there is always the risk that this or that piece of equipment will be wrongly chosen unless the choosers can benefit from the experience of others. Text-books and periodicals, useful though they are, seldom deal with the practical "wrinkles" which contribute so much to practical success; consequently, authoritative practical advice has to be sought elsewhere.

The information service provided by the Association of British Chemical Manufacturers has saved many of its members the expense of buying experience. And the person or firm seeking advice is spared the embarrassment of revealing his identity to those who are to advise him. Illustrative of the type of problem and the kind of advice which may be forthcoming is the following:

At a plant where a heat-transfer system was installed using a diphenyl oxide mixture, a difficulty was experienced with pneumatically-operated valves. The trouble was unreliable performance as well as gland leakage. The user therefore wished to replace the valves with packless valves employing bellows seals and sought advice on this point. A number of replies from different sources were obtained. One stated that for high-pressure diphenyl duty the bellows type of valve was unequalled in their experience. Another adviser recommended that the number of valves in the heat-transfer circuit be kept to a minimum. In this case no direct experience of bellows valves had been obtained, but outside screw gate valves had been used with a moderate degree of success, but frequent attention was required to keep leakage to a minimum. The Association itself pointed out that, in piping systems handling difficult vapours, it is a good practice to fit valves in such a way that a liquid seal rather than a vapour contact exists at the gland. This can be obtained by providing plenty of radiation surface on the valve body and installing the valve if necessary in the inverted position so that liquid collects at the leakage point.

The competitions organised by the A.B.C.M. have likewise been both interesting and useful. They take the form of an invitation to members to give their solutions to certain practical problems. Problems concerned with instrumentation have been used, and we give below a selection of questions along with appropriate answers which are typical to those used in the competitions.

Some Instrument Problems

Question 1 Will thermocouple-compensating cable give accurate compensation with a thermocouple head temperature of 150°C?

Answer NO It is generally accepted that, for accurate readings when using compensating cables, the head temperature should not exceed 50° to 60°C. The reason is that the alloys, from which the wires of the cables are made, only have the same thermoelectric characteristics as the thermocouple—*over a limited temperature range.*

Question 2 When installing the vapour-pressure type of thermometer, is it necessary to give any attention to the difference in height that may exist between the indicating dial and the sensitive bulb?

Answer YES When the bulb is at a higher level than the indicator, and the temperature of the bulb is higher than that of the indicator, a "head" error is introduced. In many cases, the error can be corrected by setting the pointer to the correct reading when the instrument is installed in its working position.

Question 3 A sample must be taken from a process stream operating at 1000 lb. sq. in. and fed to a *pH* controller. While it is essential to reduce the sample pressure, is it also essential to maintain a constant flow of the sample stream?

Answer YES Variations in sample flow rate introduce a variable time response or lag in the measuring system.

Question 4 A differential pressure cell is to be used for the flow measurement of a fluid where sealing is desirable. Will it be necessary to install seal chambers adjacent to the orifice?

Answer NO Since the measuring element, in this case a diaphragm, moves for full-scale range only 3/1000 in., the amount of sealing fluid displaced during normal flow measurement is negligible and can be neglected. A meter of the mercury manometer type, however, displaces a large quantity of seal and therefore requires seal chambers to obviate errors in measurement.

Question 5 The control of a level in a vessel is to be achieved by utilising a differential pressure cell, the output of which will be connected directly to the control valve through a valve positioner. Would you consider this to be a satisfactory arrangement?

Answer YES May be used on applications where averaging level control is satisfactory, where load changes are not severe and proportional control sufficient. The proportional band setting may be adjusted on the valve-positioner, the differential cell providing an indication of level and also adjusted to provide the required level position.

These competitions are a feature of the bi-monthly publication "Productivity News" and are designed to stimulate interest and also to instruct. The publication is part of the service of the Association of British Chemical Manufacturers to its members, being specially directed to the stimulation of means to higher productivity in the industry.

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HEATING AND COOLING INSIDE TUBES

A rapid method for calculating the water-side coefficient in condensers is described below

by T. FURMAN, Ph.D., B.Sc., Drft.Ing., A.M.I.Mech.E.

McADAMS' "Heat Tranmission"[12] must be the main reference book to many heat transfer engineers. But for a practical engineer not to feel frustrated at being offered correlations reliable "within an average deviation of ±20%" (reference 12, p. 202), he must have a very tolerant employer. Such is the case when one desires to evaluate the heat transfer between a tube and a fluid flowing inside it. Research workers dealing with this problem inevitably have to develop their own means to determine the appropriate coefficients for their apparatus. In a series of experiments on condensation heat transfer, the writer developed a procedure for the evaluation of water-side coefficients, which should appeal to the practical designer.

Symbols

c = specific heat, Btu/lb.;
d = diameter of tube, ft;
h_i = coefficient of heat transfer to fluid Btu/ft² hr °F;
k = conductivity, Btu/hr ft² (F°/ft);
l = tube length ft;
q = heat load, Btu/ft² hr;
t = temperature, °F;
v = fluid velocity, ft/hr;
w = mass rate of flow, lb/hr;
C = constant;
m = subscript denoting mean film temperature conditions;
b = subscript denoting bulk temperature conditions;
s = subscript denoting tube surface temperature conditions;
G = mass flow rate, lb./hr ft²;

Gz = Graetz number $= \left(\frac{w\,c}{k\,l}\right)$;

Nu = Nusselt number $= \left(\frac{h\,d}{k}\right)$;

Pr = Prandtl number $= \left(\frac{c\,\mu}{k}\right)$;

Re = Reynolds number $= \left(\frac{v\,\rho\,d}{\mu}\right)$;

ρ = fluid density, lb./ft³; and
μ = fluid viscosity, lb./ft hr.

For turbulent fluid flow (Re >2100), two basic forms of equation are usually recommended:

$$Nu = C_1\,Re_m^{\,x}\,Pr_m^{\,y} \qquad \ldots.(1)$$

$$\text{and } Nu = C_2\,Re_b^{\,\alpha}\,Pr_b^{\,\beta}\left(\frac{\mu_b}{\mu_s}\right)^{0.14} \qquad \ldots.(2)$$

Most investigators use:

$x = 0.80$ $\quad \alpha = 0.80$
$y = 0.40$ $\quad \beta = \frac{1}{3}$
$\delta = 0.14$

But values of C_1 range from 0.0178[1] to 0.0243.[12] An average value of $C_1 = 0.020$ is gaining favour with most experimenters. Whereas SIEDER and TATE[13] proposed $C_2 = 0.027$, AL-ARABI[1] recommends $C_2 = 0.0205$, for $l/d > 30$. Several authors introduce a refinement by using a correction factor to allow for entry effects and short tubes. A disturbed entry will increase the local heat-transfer coefficient, which for a short tube ($l/d < 20.5$) could considerably improve the average rate of heat transfer.[1, 3, 4, 5, 6, 7, 9, 14] The writer,[9] using a ¾-in. copper tube 12 in. long ($l/d = 20.5$), found his results correlated well with SIEDER and TATE's equation.

Generally, then, the designer can choose between the following two equations:

$$Nu = 0.020\,Re_m^{0.80}\,Pr_m^{0.40} \qquad \ldots.(3)$$

$$\text{and } Nu = 0.027\,Re_b^{0.80}\,Pr_b^{\frac{1}{3}}\left(\frac{\mu_b}{\mu_s}\right)^{0.14} \qquad \ldots.(4)$$

In Equation (3) the physical properties of the fluid are taken at some mean film temperature, usually $= \frac{1}{2}(t_s - t_b)$. At low heat loads the difference between t_m and t_b may be negligible. For higher rates of heat transfer with viscous fluids, where $d\mu/\mu.dt$ is large, this temperate difference cannot be ignored. But since the determination of t_m is bound up with the evaluation of the heat-transfer coefficient, a trial-and-error method has to be adopted when using Equation (3).

Subscript b in Equation (4) denotes that physical properties are evaluated at bulk temperature. In most practical problems the mean bulk temperature may be determined from known terminal conditions. The unknown

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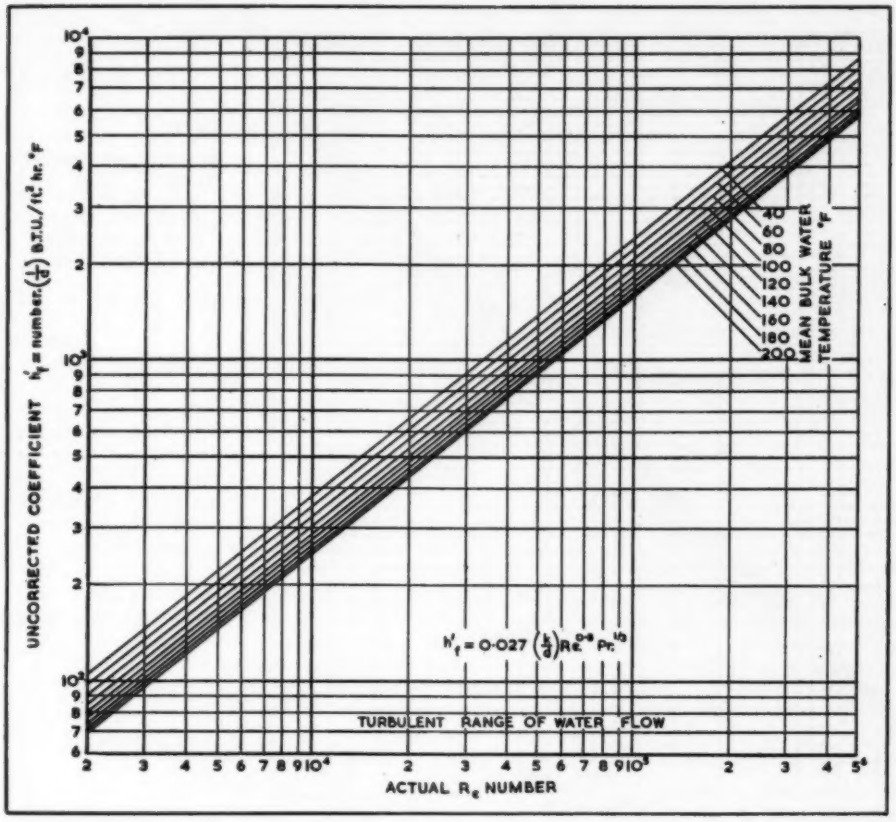

Fig. 1. Uncorrected heat-transfer coefficient between tube and water.

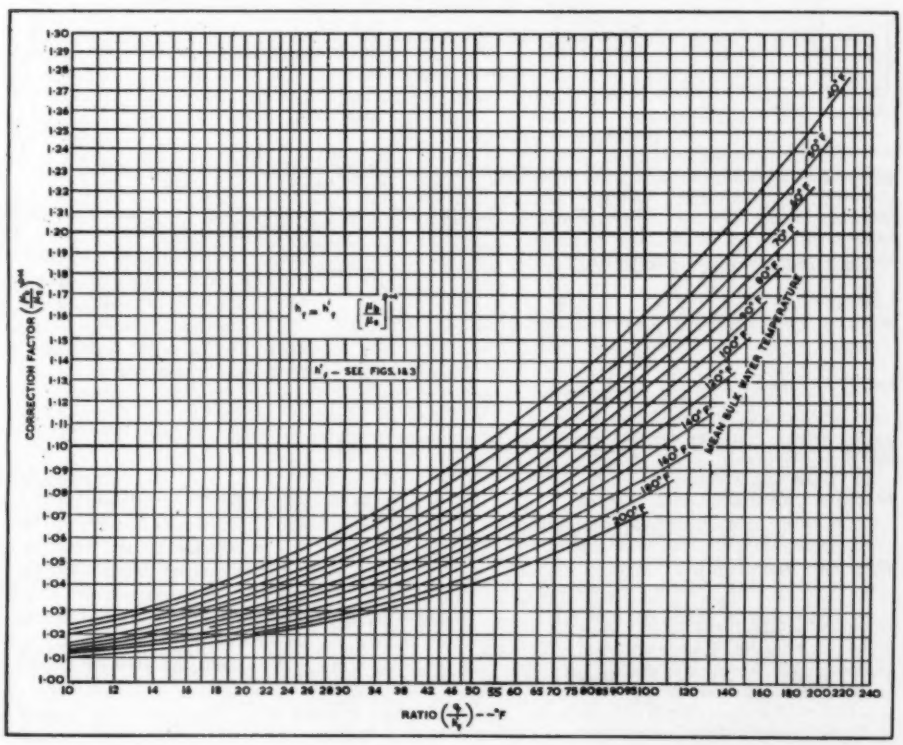

Fig. 2. Heat load correction factor for heat transfer between tube and water.

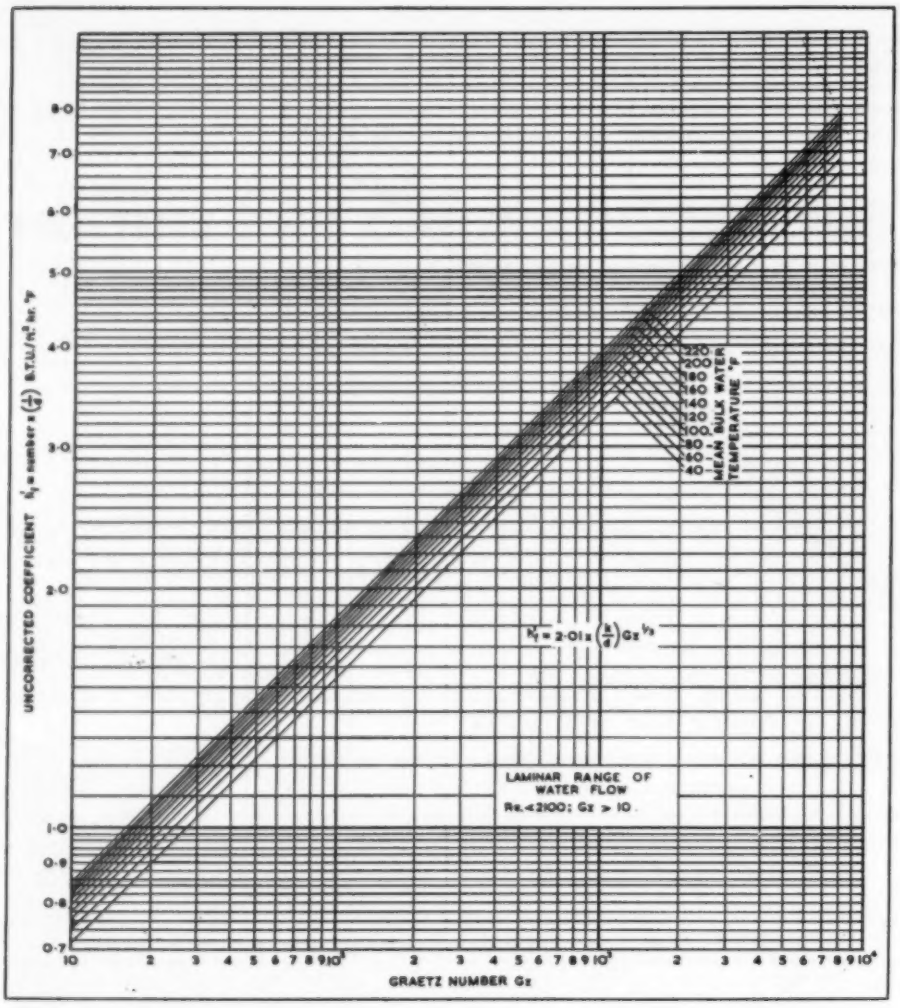

Fig. 3. Uncorrected heat-transfer coefficient between tube and water.

quantity remaining is μ_s or $\left(\frac{\mu_b}{\mu_s}\right)^{0\cdot14}$, the "heat-load correction factor", which may be "lifted" from a chart as described below:

Equation (4) may be written:

$$h_f = 0.027\left(\frac{k_b}{d}\right) \mathrm{Re}_b^{0\cdot80}\, \mathrm{Pr}_b^{\frac{1}{3}} \left(\frac{\mu_b}{\mu_s}\right)^{0\cdot14} \quad \ldots.(4a)$$

or
$$h_f = h^1{}_f \left(\frac{\mu_b}{\mu_s}\right)^{0\cdot14}, \quad \ldots.(4b)$$

where
$$h^1{}_f = 0.027\left(\frac{k_b}{d}\right) \mathrm{Re}_b^{0\cdot8}\, \mathrm{Pr}_b^{\frac{1}{3}} \quad \ldots.(5)$$

Generally we have:

$$q = h_f\,(t_s - t_b), \quad (t_s > t_b),$$

therefore, from (4b)

$$q = h^1{}_f\,(t_s - t_b).\left(\frac{\mu_b}{\mu_s}\right)^{0\cdot14},$$

$$\text{or } (q/h^1{}_f) = (t_s - t_b)\left(\frac{\mu_b}{\mu_s}\right)^{0\cdot14} \quad \ldots.(6)$$

Equations (5) and (6) lend themselves to the construction of charts of $(h^1{}_f)$ versus (Re_b) and $(q/h^1{}_f)$ versus $\left(\frac{\mu_b}{\mu_s}\right)^{0\cdot14}$ respectively. Such charts for water are shown in Figs. 1 and 2.

When using Fig. 1, Re_b must be evaluated for the actual tube diameter used. The number on the $h^1{}_f$ ordinate on the chart, corresponding to the mean bulk temperature, should be divided by the tube diameter in inches.

The method may be extended to the range of laminar flow. The general equations recommended for laminar-flow heat transfer are:[12]

$$\mathrm{Nu} = 1.86\,[\mathrm{Re}_b\,\mathrm{Pr}_b\,(d/l)]^{\frac{1}{3}}\left(\frac{\mu_b}{\mu_s}\right)^{0\cdot14} \quad \ldots.(7)$$

$$\mathrm{Nu} = 2.01\,[\mathrm{Gz}_b]^{\frac{1}{3}}\left(\frac{\mu_b}{\mu_s}\right)^{0\cdot14} \quad \ldots.(8)$$

The equations are valid for $\mathrm{Re} < 2100$ and $\mathrm{Gz} > 10$.

(N.B.—These equations are based on ideal parabolic velocity distribution, a condition which, according to BOUSSINESQ, is not established until $l/d = 130$ for $\mathrm{Re} = 2000$ and $l/d = 65$ for $\mathrm{Re} = 1000$.)

Equation (8) may be re-written as:

$$h_f = h^1{}_f\left(\frac{\mu_b}{\mu_s}\right)^{0\cdot14} \quad \ldots.(8a)$$

$$h^1_f = 2.01 \left(\frac{k_b}{d}\right) Gz_b^{\frac{1}{3}} \quad \ldots.(9)$$

We can again write:

$$q/h^1_f = (t_s - t_b) \left(\frac{\mu_b}{\mu_s}\right) \quad \ldots.(10)$$

Fig. 3 represents a plot of Equation (9), the fluid being water and $d = 1$. Fig. 2 is applicable also for laminar flow conditions (Equations (6) and (10) are identical). Charts of similar forms may be plotted for any other fluid.

If the directon of heat flow is such as to make $\left(\frac{\mu_b}{\mu_s}\right) < 1.0$, the factor obtained from Fig. 2 should be inverted.

A simple example will serve to demonstrate the use of the charts:

Cooling water enters a bank of condenser tubes at 60°F and leaves at 75°F. The tubes are $\frac{3}{4}$ in. o.d. and 5 ft long. Determine the heat-transfer coefficient between tube and water, if the water velocity is 6 ft/sec. What will be the tube surface temperature?

Assuming 16 SWG wall, d_i of tube = 0.745 in., and the mass flow, therefore, = 4075 lb./hr. (See reference 12, p. 487.)

The inside sectional area = 0.4360 in.^{2}, and the inside heat transfer area = 0.1951 ft.^{2}/ft length of tube

$= 5 \times 0.1951 = 0.976$ ft^2/tube

$$\text{Heat load} = \frac{4075 \times 15}{0.976} = 63{,}500 \text{ Btu/ft}^2 \text{ hr.}$$

$$\text{Reynolds number} = \frac{G\, d_i}{\mu_b}; \; G = 4075 \div \frac{0.436}{144},$$

and μ_b must be taken at mean bulk water temperature.

The arithmetic mean bulk water temperature = 67.5°F and the log mean = 67°F.

μ_b at 67°F = 2.47 lb./ft hr, therefore:

$$\text{Re}_b = \frac{4075 \times 0.745 \times 12}{2.47 \times 0.436} = 33{,}900.$$

From Fig. 1 we obtain for $t_b = 67$°F,

$$h^1_f = \frac{930}{0.745} = 1250 \text{ Btu/ft}^2 \text{ hr °F},$$

hence $$q/h^1_f = \frac{63{,}500}{1250} = 50.8\text{°F},$$

and from Fig. 2, for $t_b = 67$°F $(\mu_b/\mu_s)^{0.14} = 1.08$,

therefore $h_f = 1350$ Btu/ft^2 hr °F.

$$\text{Now } (t_s - t_b) = \left(\frac{q}{h_f}\right) \times \frac{1}{\left(\frac{\mu_b}{\mu_s}\right)^{0.14}} \text{ from Equation (6)}$$

$$\text{therefore, } \quad (t_s - 67) = \frac{50.8}{1.08} = 47\text{°F};$$

hence $t_s = 114$°F.

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Meetings of the Month

Institution of Chemical Engineers

April 24. *North Western Branch joint meeting with the Institute of Petroleum, Northern Branch:* At Reynolds Hall, College of Science and Technology, Manchester. "Modern Processes in Petroleum Refining." **7 p.m.**

April 30. *Thirty-sixth Annual Corporate Meeting and Dinner:* At Park Lane Hotel, Piccadilly, London, W.1.

Institution of Mechanical Engineers

April 23. *Education Group:* At 1 Birdcage Walk, London, S.W.1. Discussion: "Teaching the Fundamentals of Automatic Control." **6 p.m.**

April 25. At 1 Birdcage Walk, London, S.W.1. James Clayton Lecture: "Large Pipeline Projects". **6 p.m.**

Society of Instrument Technology

April 29. *Joint Symposium with Data Processing Section:* At Manson House, Portland Place, London, W.1. "Experience Gained in Using Logging Equipment" and "Experience Gained in Using Scanning Equipment". **7 p.m.**

Society of Glass Technology

May 6. *London Section:* At the Glass Manufacturers' Federation, 19 Portland Place, London, W.1. Two papers on "Model Furnace Work". **6.30 p.m.**

Institute of Petroleum

May 7. At the Institute, 26 Portland Place, London, W.1. "Advances in Petroleum Refining." **5.30 p.m.**

Physical Society

May 8. *Low Temperature Group:* At 1 Lowther Gardens, Prince Consort Road, London, S.W.7. "Free Radicals."

May 15. *Optical Group:* At 1 Lowther Gardens, Prince Consort Road, London, S.W.7. "Testing Large Mirrors" and "The Sutherland I.R. Vacuum Grating Spectrograph".

Society of Chemical Industry

May 20. *Chemical Engineering Group:* At 14 Belgrave Square, London, S.W.1. "Factors Involved in the Preparation of Contracts." **5.30 p.m.**

Institute of Metals

April 28. *Jubilee Spring Meeting:* At Church House, Gt. Smith Street, London, S.W.1, **until May 2.**

This Month's Events

Home

May 7. *Mechanical Handling Exhibition and Materials Handling Convention:* At Earls Court, London, **until May 17.**

May 12. *The Production Exhibition* At Olympia, London, **until May 21.**

May 15. *Open Days of Road Research Laboratory:* At Materials and Construction Division, Harmondsworth, Middlesex, **until May 16.**

May 20. *A Residential Conference for Works and Plant Engineers, organised by The National Industrial Fuel Efficiency Service, 71 Grosvenor Street, London, W.1:* At The Strand Hotel, Portstewart, Nr. Portrush, County Londonderry, **until May 23.**

May 21. *Conference of Engineers responsible for Standards:* At Connaught Rooms, London.

Overseas

April 20. *Chemical Engineering Conference—Canada and the United States:* At Sheraton Mount Royal Hotel, Montreal, P.Q., Canada, **until April 23.**

April 27. *German Industries' Fair:* At Hanover, Germany, **until May 6.**

April 28. *Engineering Societies' Conference on Western Europe and the United States of America:* At New York, America, **until May 3.**

May 10. *Liége International Fair:* At Liége, Belgium, **until May 26.**

May 12. *Annual Symposium on New Principles in Instrumental Methods of Analyses:* At the Shamrock Hilton Hotel, Houston, Texas, **until May 14.**

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CONTROL OF INDUSTRIAL PROCESSES BY CONTINUOUS PHOTOMETRY

A new design of photometer is described, with some actual and suggested applications as a process control instrument

by C. R. THEILER, Ph.D., Zürich (Switzerland)

THE suitability of photometry for determining physical properties based upon a change in colour or clarity indicates that photometry might be used to control a number of processes such as filtration, clarification, extraction and distillation as well as concentration control. The industrial continuously-recording photometer designed by the Swiss physicist Sigrist is therefore of considerable interest. This particular design differs from others through incorporating automatic optical compensation. This feature eliminates frequent manual adjustments and makes possible continuous nephelometric or turbidity measurements.

Principle of Measurement

The process stream or a portion of it is passed continuously through cell C_2 (Fig. 1). Two beams of light from the same light source are directed alternately to the same photocell, the measuring beam passing through the test fluid and the comparison beam through the comparison standard. The absorption or the turbidity value is determined through the comparison beam which is automatically adjusted by a diaphragm just enough to establish the equality of the two beams.

The mains-operated bulb *L* sends a beam of light to the reflector *R* and on to the oscillating mirror *OM*, which alternately sends a beam to the measuring branch with the measuring cell C_2 and a beam to the comparison branch with the cell C_1 containing a comparison standard. (*F* is a colour filter that can be inserted behind the oscillating mirror *OM*.)

The two beams are directed to the same photocell (Ph_A for colorimetric Ph_T for nephelometric determinations). The diaphragm *D* inserted in the path of the comparison beam automatically modifies the intensity of this beam. The initial difference between the two beams falling on to the photocell generates a small alternating current which is multiplied in the amplifier *A* and fed to the servomotor *M* which drives the scale drum *Sc*. This drum mechanically adjusts the diaphragm *D* by an amount sufficient to establish equality of the two beams. The measurement can be read off directly from the drum scale. This principle ensures that the instrument has good stability and a reproducibility comparable with instruments based upon the Wheatstone bridge. It measures absorption and turbidity solely by directing light beams and by the diaphragm adjustment. Fluctuation of the light source, variable sensi-

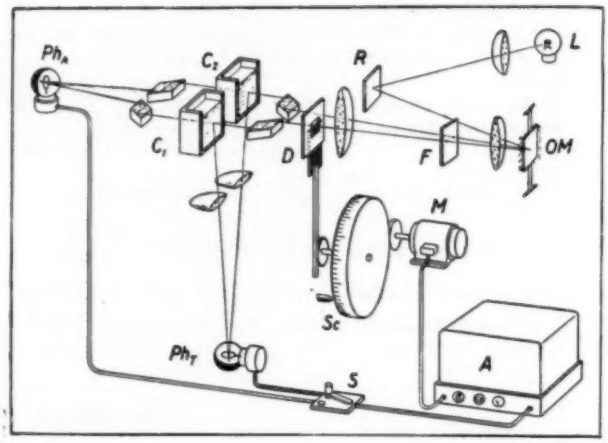


Fig. 1. Operating principle of a continuously recording photometer or turbidimeter. (Courtesy Sigrist & Weiss, Zürich.) The cell C_1 contains the solution to be examined and C_2 the solution with which it is compared. The result of the comparison is given on scale S_c.

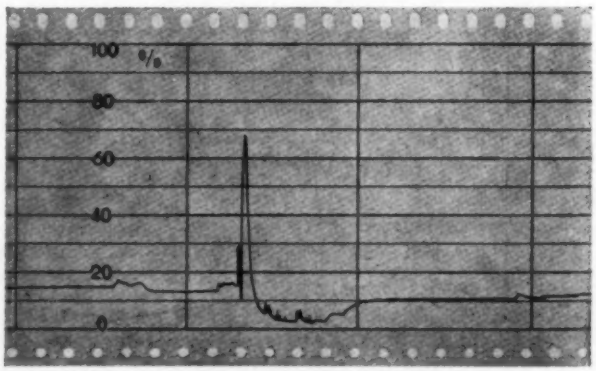


Fig. 2. A typical section of recording chart from continuous turbidimetric measurement, for a filtration process. Three batches are dealt with on the chart.

Dr. Theiler *studied chemistry and physics at Zürich, Berne and Karlsruhe. He has been for many years a consultant with extensive experience of the chemical and pharmaceutical industries of Germany, Holland and Britain.*

APPLICATIONS OF CONTINUOUS COLORIMETRY AND TURBIDIMETRY

Measurement of concentration where concentration changes are accompanied by colour changes obeying the Lambert-Beer-Boguer Law	*Processes where the desired quality can be measured by turbidity*	*Control of decolorising and purifying processes where undesirable contaminants impart a colour to the product*
Gaseous chlorine in air, in HCl gas, etc., in the range 0-50%.	Filtration of process water where the purity is of importance, as, for example, in the cellulose and pharmaceutical industry.	At petroleum refineries, treatment of kerosene, heavy oil, gas oil.
Chlorine dissolved in water in the range 50-1000 mg.	Filtration of brine prior to electrolysis.	Chemical and pharmaceutical industry, colour of triethanolamine.
Gaseous chlorine dioxide in the range 1-20% by volume.	In the pharmaceutical industry, separation of blood and sera.	In the edible oil and margarine manufacture, treatment of oils with bleaching earth and quality of finished product.
Chlorine dioxide in water (bleach solution) in the range 1-10 g/l.	In the fermentation industry, the growth of yeast and other bacterial cultures.	In sugar production, treatment of thin sap; decoloration and colour grading of the cane-sugar solution.
In general, the concentration of any liquid or gas can be measured, provided that they absorb in the visible resp. in the near infra-red resp. ultra-violet (in other words: liquide or gases that have a proper colour).	In artificial fibres manufacture, titanium dioxide concentration in viscose.	In the foodstuffs industry, control of decoloration of glutaminates.
	In the petroleum industry, coke particles in by-products and water content of main products.	
	In the paper industry, process circulating water.	

tivity of photocells and rate of amplification of photocurrent do not affect accuracy of the measurements.

As yet, continuous photometry or turbidimetry is not widely applied in industry, but it has considerable potentialities and its use is growing. Processes where the desired condition of a solution such as composition can be indicated by colour intensity, for example where concentration in a given solution obeys the LAMBERT-BEER-BOGUER Law are amenable to control by means of photometry. Liquid-liquid or solid-liquid separations also can be controlled through turbidity measurements.

Sugar manufacture offers one of the best fields for control by means of photometry. One of the principal tasks of the sugar refiner is the removal of colour from his product; he usually uses a tintometer to help him to carry out this task. This instrument can be replaced by a continuous recording photometer equipped with a colour filter. The quality of thick liquor leaving the evaporators and the bone-char treatment processes can be thus controlled; the first and second carbonatation stages of sugar manufacture may be controlled by means of turbidity measurements.

Continuous turbidimetry may be applied to centrifugation processes used for clarification of vegetable oils, beverages, lacquers and so on. Continuous measurement of turbidity makes it possible to select the best centrifuge speed for a given duty. Sometimes a high rotational speed means a low yield but a good separation, whereas a lower speed gives a high yield but a poorer quality product; the best conditions in a particular case, i.e., those which give maximum yield and a product of requisite clarity can be readily determined by means of continuous turbidity measurements.

Of considerable interest also are concentration measurements in gases, where the concentration of a given component also obeys the LAMBERT-BEER-BOGUER Law. The most interesting application is the continuous measurement of chlorine gas over a wide range of concentrations.

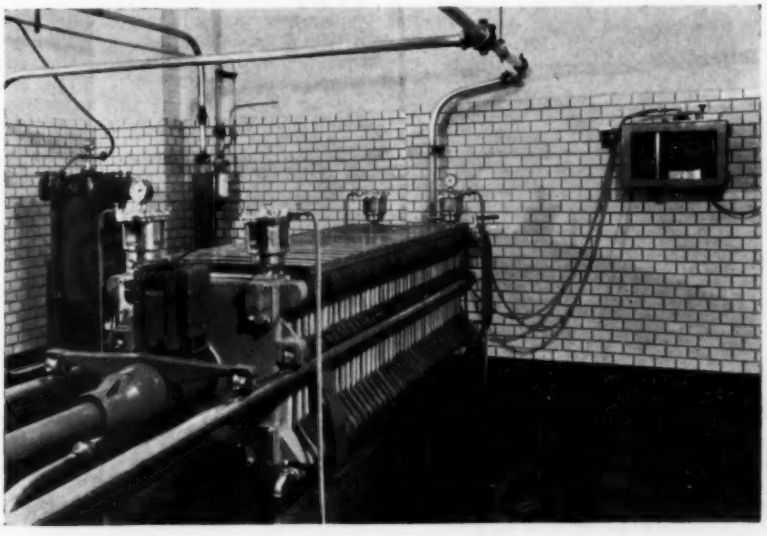


Fig. 3. A brewery filter press. The classification is controlled by means of continuous measurement of turbidity. The instrument is to the right of the filter press.

PREVIEW OF THE I.E.A. EXHIBITION

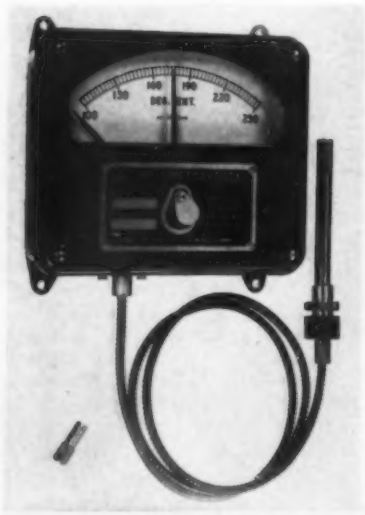
Wide Range of Instruments and Equipment to be Shown

INSTRUMENTS ranging from pocket *pH* meters to nuclear magnetic resonance spectrometers; plant and equipment from pipes, valves, to automatic weighing systems; new materials for special uses, and computers and computing equipment will be among the displays on the 253 stands at the 1958 Instruments, Electronics and Automation Exhibition to be held at Olympia, London, April 16 to 25. Below are notes on selected exhibits, new and established.

Timing equipment will be shown by a number of instrument makers. It will include a range of new elapsed time meters by COUNTING INSTRUMENTS LTD., 5 Elstree Way, Boreham Wood, Herts. VENNER ELECTRONICS LTD., Kingston By-Pass, New Malden, Surrey, will demonstrate electronic timing units specially developed for process control, delay relay applications, sequence timing and cyclic operation and batch counting. ELECTRICAL REMOTE CONTROL CO. LTD., Elremco Works, Harlow New Town, Essex, will show for the first time their newly-designed automatic synchronous process timer, type AB, for operation on up to 44v AC, and their automatic timer type AHS. New flow-measuring instruments will include the hydraulic flowmeter type 101 by GLOSTER AIRCRAFT CO. LTD., Gloucester, which will be exhibited as a fuel burner installation.

Temperature-Indicating Instruments

A range of temperature-indicating instruments will be shown by ACCURATE RECORDING INSTRUMENT CO., Garth Road, Morden, Surrey. The company's display



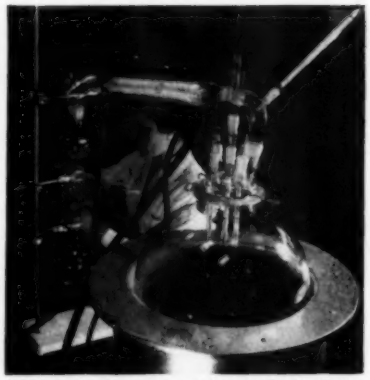
Indicating thermostat by Aric Ltd.

will also include pressure instruments and actuating units of standard and special Bourdon tubes of phosphor bronze, beryllium copper and stainless steel. The complete range of temperature-measuring and controlling instruments and equipment by FOSTER INSTRUMENT CO. LTD., Letchworth, Herts., which will be shown will include two new versions of their instruments. In the transmitting model a precision potentiometer is fitted to the main shaft of the instrument and geared to give a comparable full-scale movement. In the new digitising model a digitiser or encoding disc is coupled to the main shaft of the instrument, to convert the measured value, then in angular degrees, into a digital code. Another addition to the automatic control range is the Model 3510 resistance thermometer controller, a small cased instrument with a scale length of 15 in. and with a minimum operating differential of 0.1°C.

F. S. BAYLEY, CLANAHAN & CO. LTD., 44 Brazennose Street, Manchester, 2, who represents Degussa, of Frankfort-on-Main, are featuring a new type of measurement feeler by Degussa for establishing the dewpoint of acids. Thermocouple wire and compensating leads, which Degussa produce in accordance with all standards, and elements for resistance thermometers with nickel or platinum windings for temperatures of −200° to +850°C (maximum 1000°C) will also be on view. A rate-of-change temperature recorder consisting of a slightly modified version of the Bailey Calortron recorder and a specially designed thermocouple assembly will be among the range of instruments on the stand of BAILEY METERS & CONTROLS LTD., Purley Way, Croydon, Surrey. Their acoustic solids flow-failure alarm will be shown working in conjunction with a coal chute to pulveriser mill.

Pressure gauges of many types suitable for steam, oil, air, water, gases and other fluids will be available for inspection on the stand of PAYNE & GRIFFITHS, LTD., Tudor Works, Windmill Lane, Smethwick, together with special-purpose instruments for use with pressure systems, clocks, syphons, valves and other fittings.

The Ekco fluid density measurer which incorporates a gamma-ray source and a pressurised ionisation chamber will be shown by EKCO ELECTRONICS LTD., Southend-on-Sea. The makers suggest its use for detecting the interface between premium and regular grades of petrol in a pipeline; for monitoring pulverised coal feed to a boiler, and indicating the coal/air ratio; for measuring the density of



A glass 5-gallon reaction vessel in use for distillation under vacuum, with stirring, to be exhibited by Quickfit & Quartz Ltd.

paint in sealed tins, or for measuring coal slurry density during washing to indicate the ash content.

Level Gauges

A new development in American liquid gauges, the Gilbarco electronic tank gauge, which is to be manufactured in Great Britain under licence, will be among the equipment shown by FIRTH CLEVELAND INSTRUMENTS LTD., Treforest, Glam. It employs a level-seeking electronic device giving accuracy to within $\frac{1}{16}$ in. for deep tanks. A large number of tanks may be read in sequence on one receiving unit, and facilities for tank-contents average temperature measurement are provided. Other exhibits will include a pressure-operated switch for use as a liquid-level controller, or for operating warning systems, and an automatic sampler, which extracts a predetermined quantity from a pipeline at regular intervals.

THE GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2, will have on their stand a transistorised level-measuring instrument which, though developed for use with aircraft liquid-oxygen containers, is suitable in design for measuring the level of any liquid. As well as showing quantity, it gives warning of failure to the supply or the gauging system. Cast in synthetic resin for rigidity and freedom from moisture, it employs printed circuits and G.E.C. transistors.

Pressure gauges made out of solid blocks of methacrylate resin, for measuring pressures up to 30 in. w.g., will be featured by COMBUSTION INSTRUMENTS, 61 Belsize Lane, London, N.W.3. They are made both in portable and panel mounting forms, and the internal passages are visible.

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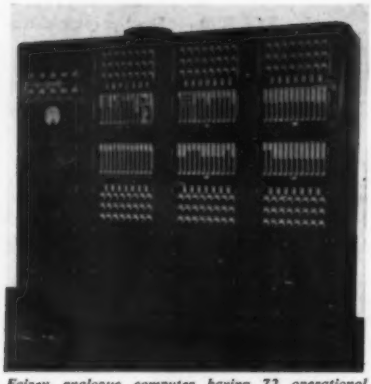

Fairey analogue computer having 72 operational amplifiers will be displayed at the exhibition.

Other Instruments

On show for the first time in Great Britain will be the Pantam range of automation measuring relays and regulators by Gossen & Co., Erlangen, West Germany. They will be demonstrated working on the stand of AVELEY ELECTRIC LTD., Ayrton Road, Aveley Industrial Estate, South Ockendon, Essex.

Industrial optical control-instruments will include a recording photo-electric refractometer fitted with temperature compensation incorporated in the recording system, and a developed version of a photo-electric polarimeter by BELLINGHAM & STANLEY LTD., 71 Hornsey Rise, London, N.19. Recent developments of the calibrated relay, which operates within close tolerances at a predetermined voltage or current setting, will form part of the display by SMITHS INDUSTRIAL INSTRUMENTS LTD., Chronos Works, North Circular Road, London, N.W.2.

Among the numerous recording instruments to be shown is the Fleming automatic air pollution recorder. It was elaborated by FLEMING RADIO (DEVELOPMENTS) LTD., Stevenage, Herts., in collaboration with the Shirley Institute, Manchester, and will be available soon in a form for measuring radioactive air contamination. RECORDER CHARTS LTD., Clyde Vale, Dartmouth Road, London, S.E.23, will show a range of precision charts; and TAYLOR CONTROLS LTD., 75 Hale End Road, London, E.17, their new Transcope miniature recorder having a panel 6 in. square and fitted with Servomatic power pens.

Grouped on the stand of LIVINGSTON LABORATORIES LTD., Retcar Street, London, N.19, will be a range of electronic instruments from 24 British, 10 American and four continental manufacturers.

Other instruments to be seen will be industrial acoustics equipment by AMPLIVOX INDUSTRIAL DIVISION, AMPLIVOX LTD., 47 New Bond Street, London, W.1; a electro-chemical dissolved oxygen analyser (gas-phase transfer type), and a residual hydrazine recorder for boiler feed plants by CAMBRIDGE INSTRUMENT CO. LTD., 13 Grosvenor Place, London, S.W.1; a new moisture meter by SHAW MOISTURE METERS, 31 Market Street, Bradford; and a flame photometer by BALDWIN INSTRUMENT CO. LTD., Brooklands Works, Dartford, Kent.

Plant and Equipment

Twin-saddle renewable hose-ends for high-pressure hoses, the latest product of BRITISH ERMETO CORP. LTD., Beacon Works, Hargrave Road, Maidenhead, will be shown publicly for the first time. The equipment, which can be fitted without preparation of the hose, with use of only two spanners, consists of a steel insert and two forged steel saddles which interlock with it. The twin-saddles are drawn tightly together by two or more high-tensile steel bolts. HUNT & MITTON LTD., Oozells Street North, Birmingham, 1, will show a range of valves designed for process control and automation in bronze, cast iron, forged steel, cast steel and all-stainless steel, and C. A. NORGREN LTD., Shipston-on-Stour, Warwicks., a comprehensive range of compressed air equipment, including air filters.

BURNDEPT LTD., Erith, Kent, will show their newly-designed high-speed batch counter and their new proximity switch which, they say, is applicable to control in any process where change in capacitance occurs. A general-purpose induction heater will be exhibited by THE BRITISH THOMSON-HOUSTON CO. LTD., Rugby, which has a continuous output rating of 25 kW and a peak intermittent rating (50% duty cycle) of 30 kW; and seamless, flexible, metallic hose assemblies will be shown by POWER AUXILIARIES LTD., Swindon.

The first public display of the new Endrock test sieve shaker of ENDECOTTS (FILTERS) LTD., 251 Kingston Road, London, S.W.19, will take place at the exhibition. The machine is fitted with anti-vibration mountings and with a built-in time switch. It will demonstrate the rapid analysis of particles on transparent rimmed test sieves.

The Endrock test sieve shaker by Endecotts (Filters) Ltd. for the rapid analysis of particles is fitted with anti-vibration mountings.

Among the numerous other demonstrations that will be staged will be one of Mobrey magnetic level switches, designed for use in the petrochemical industry, operating in conjunction with a multi-light alarm panel. It will be shown on the stand of RONALD TRIST & CO. LTD., Bath Road, Slough, Bucks.

W. & T. AVERY LTD., Soho Foundry, Birmingham, 40, will show weight control by punched-cards. With electric signals, control information is fed to the scale from punched cards. Performance data are taken from the scale for production record purposes through a punched-card machine and a printing, listing, totalising and punched tape machine.

Routine life testing of Hydroflex bellows will be demonstrated by THE DRAYTON REGULATOR & INSTRUMENTS CO. LTD., Horton Road, West Drayton, Middlesex. CROSBY VALVE & ENGINEERING CO. LTD., Wembley, Middlesex, will show four valves having transparent plastic bodies to illustrate the path of flow through the Mason Neilan percent piston control valve, angle control valve, and type 107 valve for small flows, and a Crosby relief valve.

Demonstrations will also be given by PHILIPS ELECTRICAL LTD., Century House, Shaftesbury Avenue, London, W.C.2, of the stroboscopic X-ray examination of assemblies subject to vibration and housed in opaque materials—a new application of X-rays in non-destructive testing.

An historical display illustrating the development of temperature measurement from its early origins will be shown by NEGRETTI & ZAMBRA LTD., 122 Regent Street, London, W.1.

MICROWAVE INSTRUMENTS LTD., 12 Palace Chambers, Bridge Street, London, S.W.1, will stage a demonstration of paramagnetic resonance, and a prototype N.M.R. spectrometer will be shown by THE FAIREY AVIATION CO. LTD., 24 Bruton Street, London, W.1. G. H. ZEAL LTD., Lombard Road, London, S.W.19, will show for the first time an electric contact thermometer working in conjunction with the latest plug-in-relay units, controlling predetermined temperatures.

Computers and computing equipment will be shown by AIRMEC LTD., High Wycombe, Bucks., RACAL ENGINEERING LTD., Western Road, Bracknell, Berks., and SHORT BROTHERS & HARLAND LTD., 17 Grosvenor Street, London, W.1.

New industrial materials will include Sintox, an impervious aluminium ware by LODGE PLUGS LTD., Rugby, and Daystar high-temperature covering, which can be operated in temperatures of up to 1000°C, by DAVU WIRES & CABLES, Harrow Manor Way, London, S.E.2.

The Hellfax facsimile system, said to have uses in the transmission by line or radio of engineering drawings, experimental results, formulæ and quality control information, will be shown by K. S. PAUL LTD., Great Western Trading Estate, Park Royal Road, London, N.W.10.

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AMERICAN LETTER

Spring Conferences and Expansion Plans

TWO important spring conferences will be held in North America in mid-April, and although their venues are separated widely—San Francisco and Montreal—it should be possible by using scheduled air services for chemical engineers, who so wish, to attend both.

The more specialised meeting, the Canadian and United States Chemical Engineering Conference to be held in Montreal from April 20 to 23 under the sponsorship of the Chemical Institute of Canada and the American Institute of Chemical Engineers, is expected to be attended by more than 700 leading American scientific personalities in a number of fields. Much of the discussion will be grouped in symposia covering a wide range of subjects—conventional and novel. High-temperature metals for jets and rockets, future sources of energy, noise in the chemical industry and chemical engineering problems in heavy water reactors are subjects of single-session symposia dealing with modern applications of chemical engineering. Fluid mechanics, among subjects of more general interest, will be allowed a two-session symposium, and a similar time is being devoted to "general technical papers". The ten fluid-mechanics papers will include results of work on the mechanics of moving vertical fluidised systems, orifice sprays, the behaviour of drops in stationary media, mixing on a perforated distillation plate and in continuous-flow systems, turbulent heat transfer to Newtonian fluids of high Prandtl number, and the flows of fibre suspensions and of compressible fluids.

Contributors to the miscellany of "general technical papers" include R. PARKINS, of Imperial Chemical Industries Ltd., who will speak on alternative methods of setting up control systems of continuous distillation plant and will describe practical examples in large-scale installations. Two papers dealing with the kinetics of nitrogen tetroxide and nitrogen oxide systems will be read by members of du Pont de Nemours and a colleague at the University of Delaware. J. J. CARBERRY, du Pont de Nemours, has developed a correlation in the nitrogen oxide-water system on the basis of nitrogen tetroxide as the reacting oxide with water. J. T. HUGILL, L'Air Liquide, is to describe in detail a 100-ton-per-day oxygen unit designed for the supply of high purity oxygen for the steel industry. Fluidised beds are dealt with in three papers. GEORGE UASUI, Lockheed Aircraft Co., and L. N. JOHANSON, of the University of Washington, describe in their paper on this subject the measurement of some characteristics of gas pockets rising through beds of fluidised solids by the use of a light-probe technique.

Statistics in chemical engineering and modern engineering construction techniques will form the subjects of other symposia. The role of statistics in the "strategy of chemical experimentation" will be discussed by S. L. ANDERSEN, du Pont de Nemours, and his colleague, D. W. MARQUARDT, will read a paper on the techniques for the least-squares fitting of non-linear chemical engineering mathematical models. To the broader discussions TRUMAN L. KOEHLER, of the American Cyanamid Co., will contribute a discourse on the philosophy and experience of "evolutionary operation"—a procedure that he describes as "even more than a method for optimising a process without disturbing production".

Another representative of British indusry, DR. R. HOLROYD, deputy-chairman of Imperial Chemical Industries Ltd., will open a three-session symposium on the European chemical industry. Other speakers in it will include MR. J. J. DESPORTES, president-director general of Etablissements Kuhlmann, Paris; DR. R. S. JANE, president of Shawinigan Chemicals; PROF. ING. KARL WINNACKER, president of Farbwerke Hoechst A.G., Frankfurt; DR. GUILIO NATTA, University of Milan; and DR. P. FERRERO, Société Carbo Chimique, Petre. At the third session two speakers from the Soviet Academy of Science will address the conference.

Preceding the Chemical Engineering Conference by a few days, the 133rd national meeting of the American Chemical Society will be held in San Francisco from April 13 to 18, under the chairmanship of PROF. RICHARD WISTAR, head of the Mills College department of physical sciences. Five thousand chemists and chemical engineers from all parts of the United States and several foreign countries are to take part in its 21 sections. Exotic rocket fuels, food additives and conservation of water are among the themes to be discussed, and symposia are to be held on gas and fuel chemistry, industrial and engineering chemistry, petroleum chemistry, chemical literature, chemical marketing and economics, and the history of chemistry. In conjunction with this meeting, the Third Pacific Chemical Exposition of the Society's California Section will be held at the city's Civic Centre Exhibit Hall. An employment clearing-house, where chemists and chemical engineers seeking new positions can meet with employers, will also be conducted in the Hall.

Expansion and the Business Slump

No signs of the current industrial recession are shown by the American chemical manufacturers' plans for plant extension during 1958 and 1959 which according to a survey just completed by the American Manufacturing Chemists' Association, provide for $2.54 billions' worth of new construction, slightly more than in the period 1957-58. Last year the industry, now America's third largest in respect of assets (its assets total $19.6 billion), completed 309 "construction projects" at a cost of $1.3 billion. Texas, the second largest chemical-producing State in the U.S.A. (behind New Jersey), was the State again receiving the greatest share ($864.5 million) of the total investment for 1957. The greatest share of plant to be built in the period 1957-59, when divided according to products, goes to general organic chemicals ($987 million). General inorganics, at $710,521,000, are in second place, followed by metals such as zirconium, titanium, niobium, boron, tantalum, vanadium, beryllium and uranium.

That the chemical industry is, in fact, weathering the business slump better than most is the opinion both of the American Chemical Society and of Wall Street analysts. The financial experts point out that there have been no widespread lay-offs in employment in the industry. Some inventory reductions in chemicals at the end of the year resulted in cuts here and there in working forces, but recent evidence indicates the trend may be reversing. Moreover, business is still "booming" for the drug companies, they say.

No. 5 *of a series*

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SPECIFIC HEATS OF MIXED PETROLEUM VAPOURS

by D. S. DAVIS, *Head, Department of Pulp and Paper Technology, University of Alabama*

For mixed petroleum vapours at pressures below 50 lb./sq. in. abs., BAHLKE and KAY[1] correlated the specific gravity of the condensed vapours, the temperature of the vapours and the specific heat of the vapours by means of the expression

$$C_p = \frac{(4.0 - s)\,(t + 670)}{6450}$$

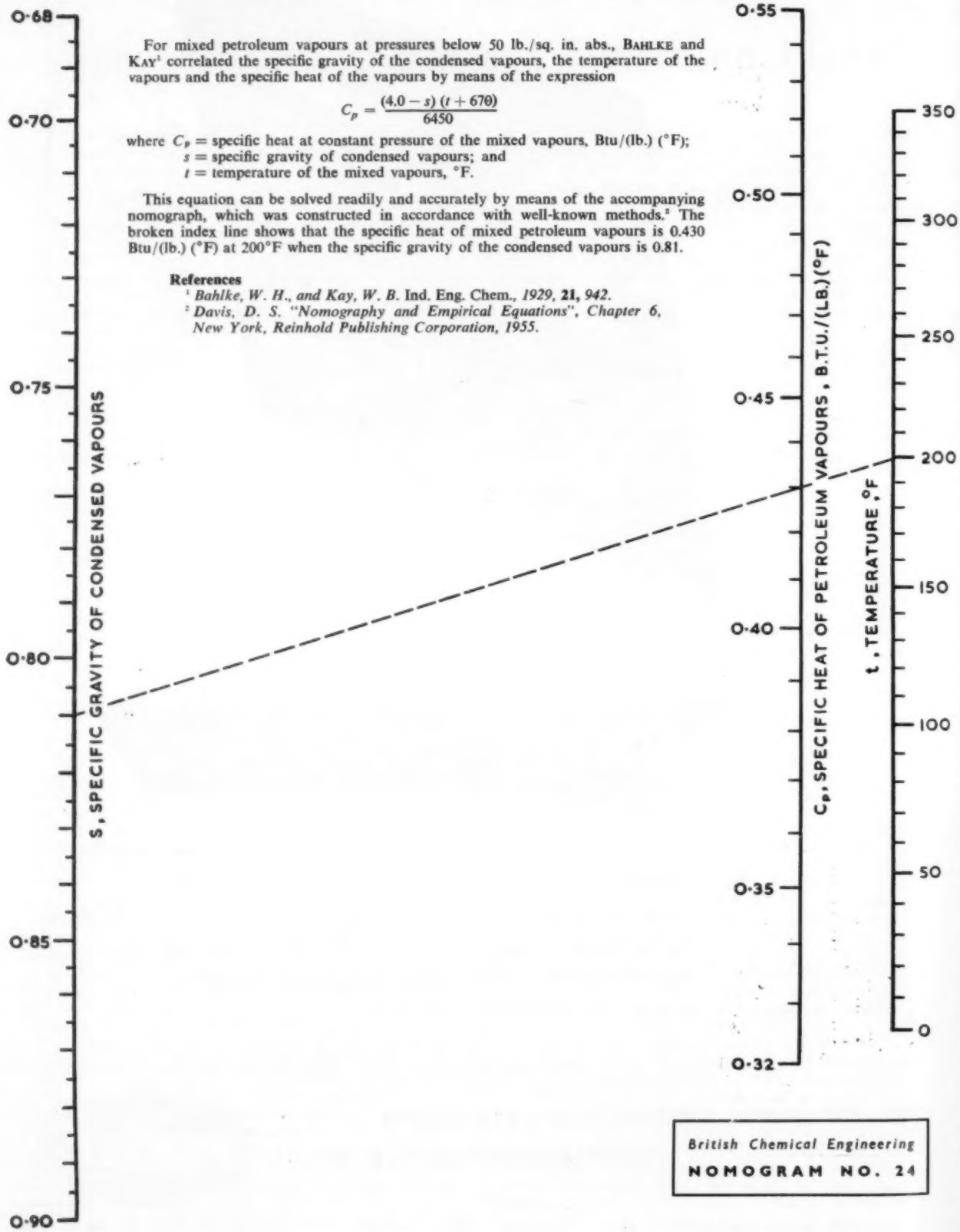
where C_p = specific heat at constant pressure of the mixed vapours, Btu/(lb.) (°F);
s = specific gravity of condensed vapours; and
t = temperature of the mixed vapours, °F.

This equation can be solved readily and accurately by means of the accompanying nomograph, which was constructed in accordance with well-known methods.[2] The broken index line shows that the specific heat of mixed petroleum vapours is 0.430 Btu/(lb.) (°F) at 200°F when the specific gravity of the condensed vapours is 0.81.

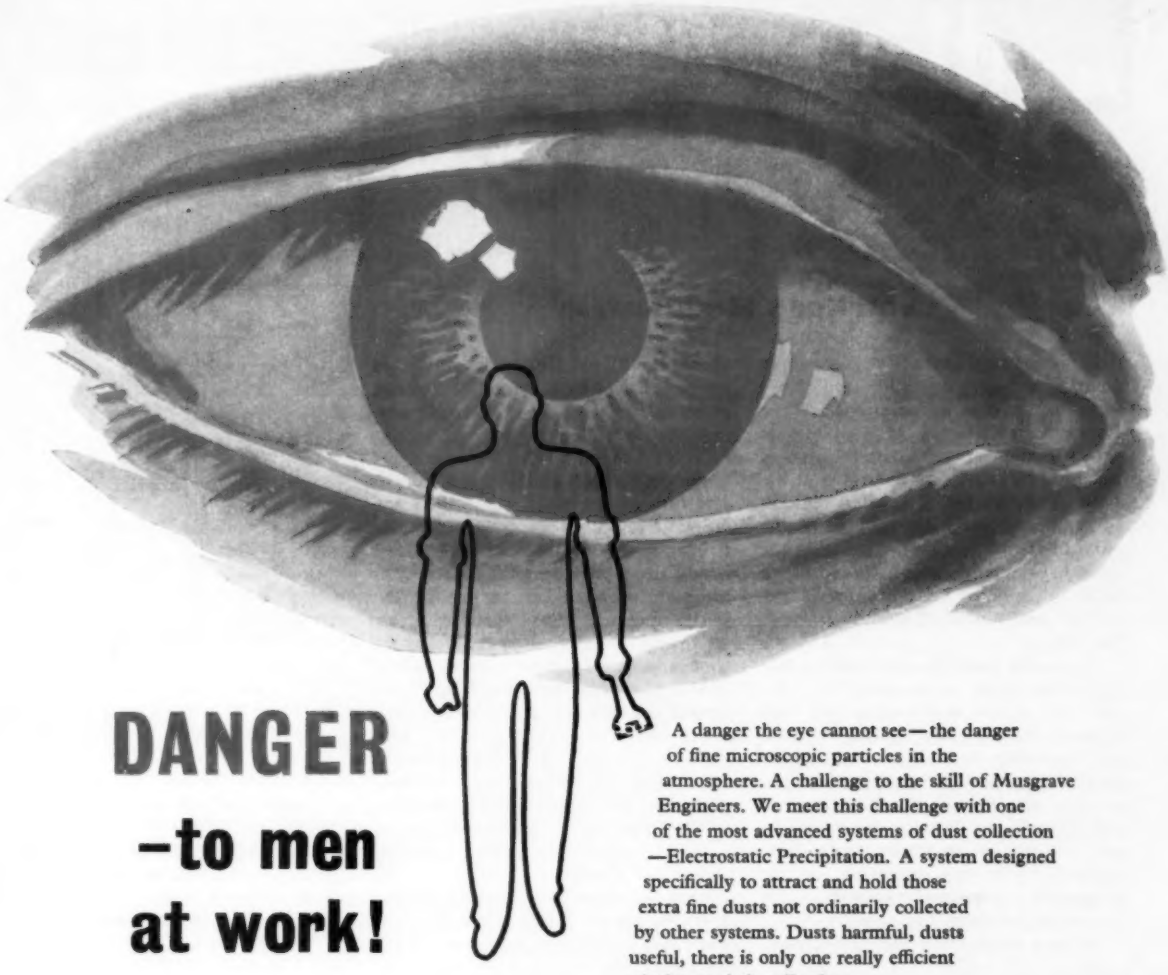
References

[1] *Bahlke, W. H., and Kay, W. B.* Ind. Eng. Chem., *1929*, **21**, *942*.

[2] *Davis, D. S. "Nomography and Empirical Equations", Chapter 6, New York, Reinhold Publishing Corporation, 1955.*



British Chemical Engineering
NOMOGRAM NO. 24



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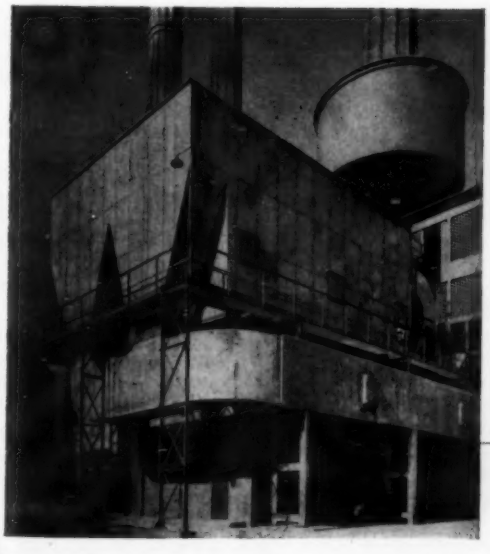

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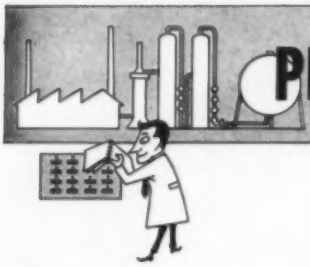


PROCESS ENGINEER'S NOTEBOOK

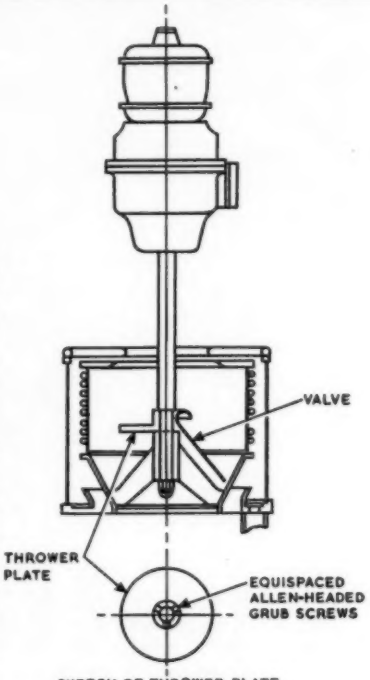
Centrifuge Modification

IT IS FREQUENTLY necessary to centrifuge heavy metallic salts from aqueous or organic solutions. If the heavy slurry is fed at a moderate speed to the normal batch centrifugal machine by means of the valve at the base of the basket, it is often difficult to obtain an even distribution of the cake over the screens fitted inside the basket. Frequently, the cake builds up as a thick layer on the sides at the bottom and tapers off rapidly towards the top.

When the washing cycle takes place the water tends to by-pass the main body of crystal at the base and runs through the thin cake at the top. It is also necessary to lean over the basket to withdraw the valve from the base so that the crystal can be ploughed out through the bottom discharge. In addition to causing a break in the production cycle, this operation can be extremely unpleasant especially if hot corrosive solutions are present.

At one plant these difficulties were overcome by replacing the valve on the centrifugal by a machined thrower plate as indicated in the accompanying sketch. This thrower plate was fabricated in mild steel and machined to reduce slight out-of-balance forces. The hub of the plate was drilled and tapped for three equally-spaced ¼-in. B.S.W. grub screws with Allen key heads, these providing the location for the plate on the centrifuge shaft. The positioning of the thrower plate along the shaft had to be fixed by trial and error, commencing at the base of the basket just above the spider and moving upwards until the slurry, when charged into the plate, gave a parallel-sided cake. It was found that the effect of the thrower plate was enhanced by the fan effect of the spider in the bottom discharge.

On completion of the charging, centrifuging and washing cycle the crystal was ploughed out through the open discharge. Using this method it was possible to seal the top of the centrifuge completely. A couple of perspex sight windows fitted to the cover allowed the performance of the centrifuge to be observed.

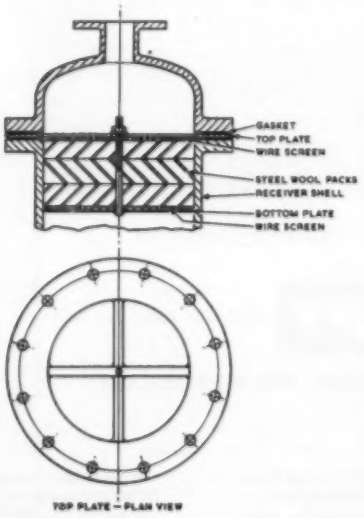


SKETCH OF THROWER PLATE FITTED TO REPLACE VALVE

F. MOLYNEUX.

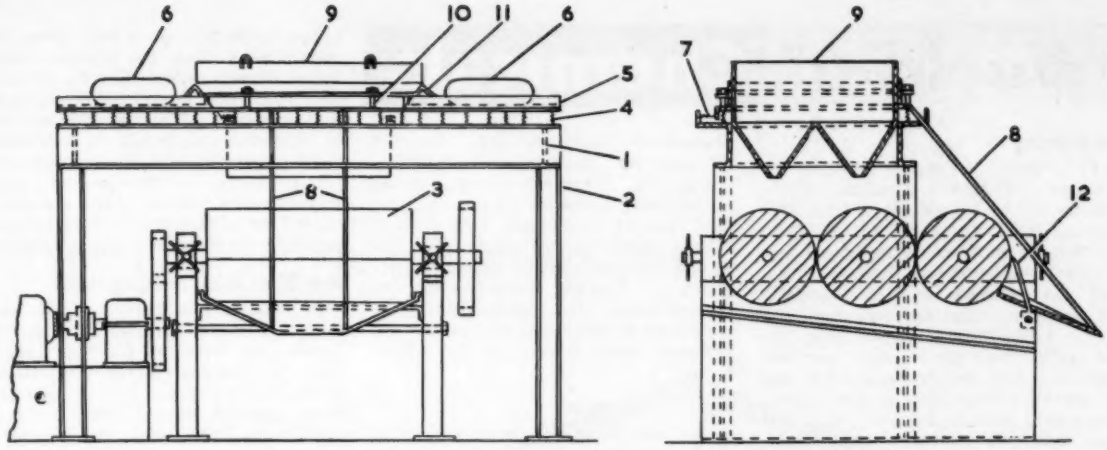
Increased Flexibility in Steel Wool Demisters

THE PRACTICE OF installing preformed steel-wool pads in vessels to minimise liquid entrainment in gases and vapours calls for considerable judgment in determining the necessary mesh density, wire diameter and overall thickness required to maintain the entrainment ratio below that demanded by a particular process. To make the initial assessment less critical, an arrangement has been devised to give the system some flexibility by making it possible to simply adjust the density of the wool to suit a stipulated duty. An example of this method is shown in the accompanying diagram, where a demister unit was installed in a cast-iron separator receiving wet gas from a liquid seal compressor.



The unit consists of two fabricated plates, the lower one having a screwed rod welded centrally on the supporting straps. Three layers of preformed 2-in.-thick steel-wool pads, the diameters of which are equal to the inside diameter of the separator, are placed between the plates, being bounded at both ends by woven wire screens. Compression is applied to the wool through the nut and the bottom plate. The steel wool can be used either in random lengths or, if required, be preformed to a certain specified density. To avoid undue bulging of the wool between the plate supports, it is necessary to fit woven wire screens that combine a high percentage free area with sufficient strength to resist bending.

The material of construction would depend on the process gas or vapour involved, while the pressure drop across such units is in the region of 6 in. water gauge per foot thickness, for pads composed of steel wool of from 0.001 to 0.002 in. diameter with densities up to 15 lb./ft.^{3} Modified versions of this arrangement can be used in pipelines and cylindrical separators where the inside diameters are small, the principal advantage being the ease with which the entrainment separation efficiency can be varied.



Vibrating Unit for Mechanical Feeding and Discharging of Colour Grinding Mills

IN OUR FACTORY we have developed and successfully tested a vibrating unit for the mechanical feeding and discharging of colour-grinding mills, as shown in the accompanying diagrams. A metal welded frame (1) on uprights (2) is mounted over a three-roll colour-grinding machine (3), so that its longitudinal axis is between the first and second rolls. On the upper surface of the frame are welded 70 equally-spaced guide rods (¼-in. lengths of tubing of ¾ in. diameter) over which automobile valve springs (4) are slipped (diameter of wire 3 mm, diameter of springs 33 mm, length 85 mm, number of turns eight). On these springs rests a welded frame (5) with similar guide pieces, but which are turned downwards: Two vibrators are also mounted on this frame. Horizontal movement of the frame is limited by springs (7) fitted at eight points. Frame 5 is connected with the apron of the machine by means of draw-rods (8), through which vibration is transmitted.

Bunker 9 of 900 lb. capacity (weight of one batch) is disposed on frame 5 and fastened thereto by means of four bolts (10) welded to the frame. For added strength and rigidity, corner pieces (11) are welded to the bunker, and also serve as supports. A scraper (12) is mounted on the base but is not connected to the apron.

The bunker, filled with the batch to be ground, is fed from the mixer by a mono-rail telpher. After the bunker has been fixed on the vibrating frame both vibrators are switched on (by means of a common starter), and the mix begins to fall on to the roll and is discharged from the apron into the receiver. Slot dimensions of the bunker (9) (width 1¾ in., length 30 in.) have been chosen from experience to deliver all the mix from the bunker to the rollers within 15 min. (the determined length of a cycle in grinding one batch); but flow from the bunker will not take place unless the vibrators are started. The amount of mix fed to the rolls may be regulated by starting and stopping the vibrators.

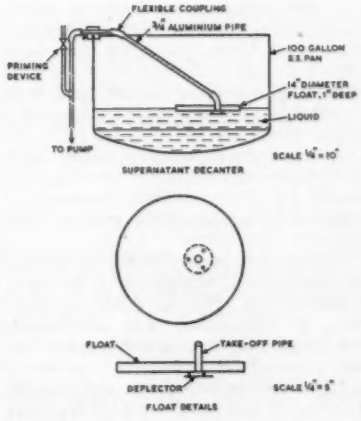
The method described eliminates hand labour. The unit is simple in design and operation and is easily made.

S.I.K.

A Supernatant Decanter

THE APPARENTLY SIMPLE job of taking off supernatant fluid from a settling pan caused repeated difficulties on a pilot plant because only a non-priming pump was available and one operator had to perform all the duties. Accordingly, a decanting device was constructed consisting of a floating take-off supporting a flexible piping system. As can be seen in the diagram, a 14-in. diameter float consisting of soldered steel sheet carries a light aluminium arm. In this way the inlet is always situated an inch below the surface. By means of a deflector plate, the flow into the pipe is radial rather than direct and so the minimum disturbance is caused in the pan. The pump is primed by means of a side arm which is filled with water to the level of the pan edge. Once this is achieved no attention is required and the decanting can be controlled simply by adjusting the pump delivery. When decanting is complete the float sits on the sludge, the inlet becomes exposed and the syphon to the pump is broken, so preventing a serious amount of solid being pumped out.

M. C. REECE.



Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Oil Refining

The capacity of Empresa Nacional Del Petroleo's (ENAP), Concon, Chile, refinery will be expanded by 24,000 BPD through the addition of a 24,000-BPD atmospheric and vacuum distillation unit, a 12,000-BPD Orthoflow fluid cat cracker and gas recovery unit, a 6000-BPD cat desulphurisation and reforming unit and a 1100-BPSD alkylation unit. The cat cracker and gas recovery unit will operate at 60% conversion and will also be capable of operation at 48% conversion and at reduced capacity. The alkylation unit will produce aviation-grade gasoline. Low-octane naphtha distillate will be charged to the desulphurisation and reforming unit to obtain a high-octane reformate. Part of the gas produced will be recycled and the balance will be sent to the gas-recovery unit. Before entering the reforming section, the naphtha will be desulphurised. The new plant is being designed by Kelloggs, New York, and constructed by the State Petroleum Enterprise (ENAP). Eventually, the plant is to be expanded to take 44,000 BPD.

Production of petroleum by ENAP in Magallanes during 1957 totalled 689,499 cu. m., as against 563,146 cu. m. in 1956. The Chilean wells now supply 62% of the country's needs of crude oil.

In Brazil the foundation stone for the Rio de Janeiro refinery, which is planned to have a capacity of 90,000 BPD, was laid by the President of the Republic recently.

Pemex (Petroleos Mexicanos) have announced plans for extensions of their oil refineries at Ciudad Madero and Azcapotzalco, Mexico, at a cost of 400 million pesos.

Developments at Norske Hydro

Although Norske Hydro considerably improved their capacity for producing heavy water during the past year, by enlarging their plants at Saheim and Glomfiord and erecting a new plant at Vemork, the organisation actually produced less heavy water during the year than in 1956, because of difficulties in supplying water to the hydro-electric power plant. A new power station has been built, however, which will increase the firm's power by at least 15,000 kW. The new installations cost Norske Hydro 68½ million kroner (£3.42 million) last year. Of this, 38 million kroner has been invested at Rjukan; 16.6 million at Erdanger; 10.7 million at Notodden; and nearly 3 million at Glomfiord. At Rjukan, in addition to a new power plant being built, the capacity for producing rare gases has been increased.

At Erdanger a new calcium carbide plant has been installed and the P.V.C. plant capacity increased to an annual output of 5000 metric tons. Factories for the manufacture of urea and for magnesium castings and alloys have also been installed. Almost 229,000 metric tons of nitrogenous chemicals (as elemental nitrogen) were manufactured in 1957—nearly 85% of the entire output of the Scandinavian countries. During the year 8600 tons of magnesium, 2400 tons of P.V.C., 18,000 tons of caustic soda and 22,600 tons of calcium chloride were produced. Receipts amounted to 457 million kroner—the highest ever in the company's history—and they surpass the previous year's figures by 66 million kroner.

Paper Production

The new paper mill being erected at Tuxtepec, Veracruz, is nearing completion, and when in operation should produce 120 tons of newsprint a day—about half the needs of the country. Capital to the extent of 180 million pesos (about £5 million) is being invested in the mill, and 80% of its machinery is of United Kingdom manufacture.

Synthetic paper from artificial fibres, such as those of nylon, is to be made by The Special Manufacturing Co., of Shizuoka, Japan. The process, developed by Okamura Technology Laboratory of Kyotot University, is thought to be the first of its kind to be put on a commercial basis. The cost of the new products is expected to be four times that of conventional papers.

In Chile a plant for the production of cellophane paper has been commissioned at Quillota by Raylon Said Industrias Quimicas, S.A. At the end of 1958 output is expected to meet all Chile's needs and to leave an exportable surplus valued at $1.6 million, which is to rise later to $5 million.

In 1957, production of Swedish chemical pulp reached a new record of 3.29 million tons, including some 920,000 tons of pulp for use in integrated production of paper and board. The Svenska Cellulose Co. have commissioned their new paper mill at Ortviken, and a second machine to be installed within the next 12 months will double the capacity of the plant to 160,000 tons.

Plastics and Plastic Chemicals

A new high-impact polystyrene plastic plant which is being built in Rhodes, New South Wales, for C.S.R. Chemicals Pty. Ltd., under licence from Dow, is shortly to come on stream, and it is expected to be able to meet all Australian requirements for the product.

The first Brazilian polyethylene plant at Cubatao, which has just been commissioned by Union Carbide do Brasil, is expected to produce 4500 tons of polyethylene annually.

Japan's first plant for the production of acrylamide is being built by the Nitto Chemical Co. The acrylamide will be used in conjunction with acrylonitrile for the production of mixed polymers for use as synthetic resins, and as a raw material for synthetic fibres and synthetic rubbers. A new synthetic fibre has been developed by Toyo Koatsu Industries of Tokyo to the pilot-plant scale under the trade name Urylon. The fibre is a polymer of monamethylene diamine and urea, the former being made from dibasic acids from whale oil, tall oil and other sources. W. R. Grace Co., U.S.A., is understood to be negotiating with the Japanese firm for a licence to the process. Eight Japanese firms have concluded a contract for 338 metric tons of hard vinyl chloride piping to the Burmese Defence Ministry.

New Blast Furnace Equipment

In India a new battery of 26 coke ovens has been inaugurated at the Jamshedpur Works of the Tata Iron & Steel Co. The first of two blast furnaces ordered by the Indian Iron & Steel Co., from Ashmore, Benson, Pease & Co. of Stockton-on-Tees, went into operation recently, over two months ahead of schedule. It has a rated capacity of 120 tons of iron a day.

The Royal Netherlands Blast Furnaces at Ijmuiden have brought a new oxy-steel plant into operation, thereby raising their potential annual output to 1,100,000 tons, against 700,000 tons previously. The oxy-steel plant is the second stage in the company's extension programme.

Commercial Developments in Japan

Ishikawajima-Foster Wheeler Co. Ltd. has been formed in Tokyo jointly by the American Foster Wheeler Co. and Ishikawajima Heavy Industries, with a capital of Y5 million—the two parent companies participating 50/50. The company is to manufacture chemicals and refine petroleum and vegetable oils, with the American firm supplying technical guidance. Schering A-G of Berlin has established a subsidiary in Japan under the name of Nippon Schering Ltd. for the manufacture of pharmaceuticals. To consolidate further their interests in East Asia Scherings have acquired a 50% shareholding in their former Japanese agents, Nishidoko Yakuhin K.K. Scherings are also to form a holding company in Japan for their patents and trademarks.

Fertiliser Production

The Trinidad Government has granted to W. R. Grace & Co. pioneer status to establish a $19 million fertiliser industry in the colony.

In Pakistan the Rs. 8 crores fertiliser factory of P.I.D.C. at Daud Khel has started production and will manufacture 50,000 tons of ammonium sulphate a year. In Chile S.A. Cemento Juan Soldado Consolidada complain that they are unable to compete with imported fertilisers and have requested permission to close their phosphate fertiliser plant near Coquimbo.

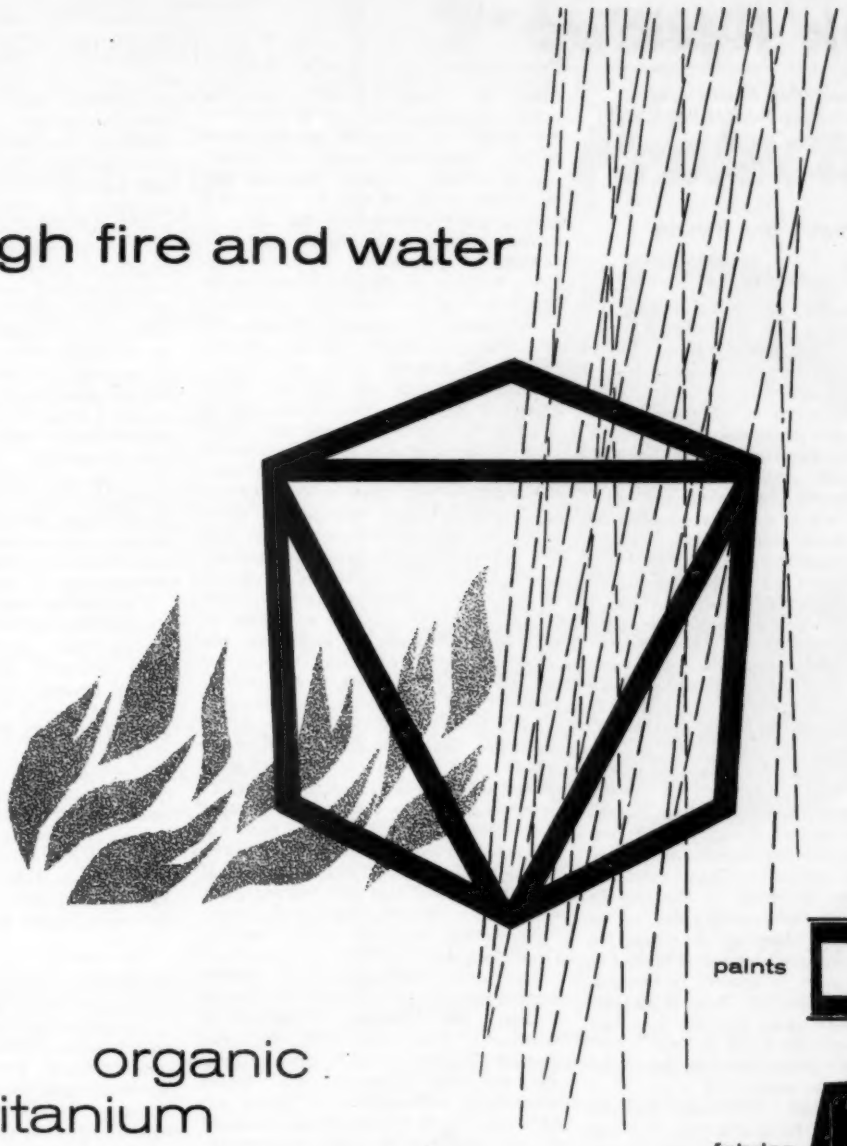
Halogen Production

The production of chlorine in Sweden at present, the managing director of A.B. Svenska Klorfabrikanter announced recently, is about 15,000 tons a year—from six factories.

In Mexico Du Pont are to invest initially 125 million pesos in a fluoride plant possibly to be installed at Monclova.

BCE 3028 for further information

through fire and water



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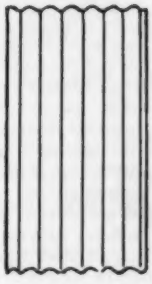
fabrics

These compounds are being used in increasing amounts in the improvement of water repellent finishes for textiles and as aids to the solvent and heat resistance of surface coatings. They also find application in the control of thixotropy in various paint media and as pigment dispersion agents.

plastics



Reprints will be available shortly of articles written by Dr. H. W. Chatfield, PH.D., F.R.I.C., M.I.CHEM.E., dealing with the use of butyl titanate in the manufacture of paints. You are invited to write to us for copies.

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Book Reviews

Nuclear Engineering Monographs
Vol. I—Elementary Nuclear Physics
by W. K. Mansfield
60 pp., 10s 6d.
Vol. II—Nuclear Reactor Theory
by J. J. Syrett
80 pp., 12s 6d.
Vol. III—Reactor Heat Transfer
by W. B. Hall
68 pp., 10s. 6d.
Temple Press Ltd., London, 1957.

THIS new series of nuclear engineering monographs aims at providing a broad treatment of the principles and theory involved in the design of nuclear fission reactors. The series is a valuable addition to the literature, in that subjects previously grouped in expensive publications have been separated into monographs of low price and convenient form. Each volume is intended as a short text-book for students and as a source of information for those engaged in nuclear engineering practice.

Two difficulties arise in editing such a series. It is important to define to whom the information is directed and here some confusion exists between the publisher's note and the introductory remarks of the authors. Secondly, the editing must be carried out carefully if the essential unity of nuclear reactor plant design is not to be overlooked.

MR. MANSFIELD has done well in the selection of subjects for the first monographs, covering as they do both fundamental and applied theory and placing emphasis on the importance of reactor heat-transfer problems. Some criticisms can, however, be made of the way in which certain vital concepts fail to be linked to the subject as a whole. In Vol. I, delayed neutrons are defined, but their importance to control is ignored. Similarly, a reading of Vols. II and III does not make clear the fact that fuel element design and single channel conditions are the starting points in the evolution of a reactor core.

The first volume, "Elementary Nuclear Physics" by W. K. MANSFIELD, is based on lectures given at Queen Mary College and describes the basic elements of atomic physics, the modes of disintegration of the nucleus and the concepts of neutron flux, cross-section and activation. It includes a useful chapter summarising the principles involved in the detection of nuclear radiation. Particular attention has been paid by the author to clear definitions of phrases widely used and accepted in the nuclear industry.

The monograph by J. J. SYRETT follows naturally from the first volume. It deals with nuclear reactor theory and the author has had an unenviable task in attempting to compress his subject-matter into 76 pages. He has succeeded in doing so by confining his attention to fundamental principles and their application to the gas-cooled, graphite-moderated reactor. In the first three chapters the diffusion theory of thermal neutrons is discussed and the processes whereby fast neutrons are slowed to thermal energies are analysed. The main body of the book covers the calculation of critical size using the approximate steady-state one-group diffusion equation and the more accurate two-group theory. The critical size of a bare sphere is calculated and the reader is led to considerations of a bare cylinder followed by the effect of neutron reflectors. The chapter on lattice calculations introduces the basic four-factor formula and the departures necessary from simple theory when a practical reactor lattice is considered. The illustrative examples included in the text are particularly helpful.

The monograph on "Reactor Heat Transfer" by W. B. HALL is not only of interest to reactor students, but could be recommended as a sound volume on heat transfer in which reactor channels and coolants are used as examples of specialised gas-solid, heat-transfer problems. The book is in three sections. The first covers the fundamentals of convective heat transfer; the second, problems of heat transfer in the reactor core, while the third section discusses a number of related topics and, in particular, the problems associated with the use of liquid metals. A number of minor criticisms can be made. It is surprising that no reference is made to GINNS, who first developed the generalised equation for temperature distribution in a channel quoted on page 32. The optimisation of pumping power to channel heat output is discussed at some length in Chapter 2, but the discussion of alternative coolants is too brief and insufficiently critical. It should be noted that this volume gains a little over the other two in that carefully worked examples have been included wherever possible.

The above monographs are supplemented by a list of references for further reading, and indexing throughout is thorough and accurate. While the series as a whole will always be open to criticism for what is omitted, the authors have done well within the limits set. Although they would have been enhanced by the addition of more worked examples and a well-chosen series of problems, they are certainly suitable as an introduction to the nuclear field for engineers and physicists.

B.E.E.

Vector Analysis
by Louis Brand.
John Wiley Inc., New York, Chapman Hall Ltd., London, 1957. 282 pp. 48s.

PROF. BRAND is the author of two larger treatises: "Vector and Tensor Analysis" and "Vectorial Mechanics". The present volume "presents the fundamental theory needed by mathematicians, physicists and engineers" followed by chapters on dynamics, fluid dynamics and electrodynamics. In this preface the author justifiably states that a short book on vector analysis cannot also be a treatise on mathematical physics and that rigid dynamics and elasticity have been regretfully omitted.

In the reviewer's opinion, the book is likely to be attractive to mathematicians but not to most engineers. In teaching mathematics to engineering students it is almost essential to anticipate the question "What's it for?" by introducing a new idea with reference to old knowledge; for instance, scalar product and work done by a force, vector product and moments or rotation. In his first five chapters PROF. BRAND develops elegantly and logically vector algebra, differential geometry, div, grad, curl and the important integral theorems, with little reference to the knowledge which a British reader, at least, could be expected to have of applied mathematics. The engineer who worked through all this would certainly be disappointed in the chapter on dynamics. The vector notation is seen to be useful in finding planetary orbits, but the final set of problems on energy are at a level of G.C.E. They need no knowledge of vectors which are relevant only because they have been used in the derivation of the energy principle from NEWTON's laws. Later in the book ARCHIMEDES' principle is obtained from surface and volume integrals, but its author saw it in a flash of intuition which we can now all share.

The chapters on fluid mechanics and electrodynamics are more rewarding. A mature reader, having in view the concrete objective of understanding the vector presentation of these subjects, would very likely be prepared to do the abstract thinking needed in the earlier chapters.

The book is well written, with worked examples in the text and problems, with answers, for solution by the reader. It can be recommended to the engineer if he is interested in mathematics for its æsthetic appeal as well as for its use. The final chapter on vector spaces is definitely for the mathematician.

C. G. PARADINE

Graduates in Industry
Allen & Unwin, London, 1957. 261 pp., 30s.

TO FOLLOW UP their report on graduate employment, P.E.P. have now issued a second report on industry and the university graduate. They set out to investigate the policy and practice of British industrial undertakings in respect of the recruitment, training and employment of university graduates. Questionnaires were sent to one in two of the 13,500 men who graduated in an arts subject or in science or technology in the academic year 1949-50. The effective response was 66%. The final conclusion —"that the majority of the members of management interviewed were satisfied with the outcome of their policy and practice, and the majority of the graduates were satisfied also"—seems remarkably complacent in view of the fact that it was early admitted that the material does not lend itself to exact analysis. The general shortage, particularly of science and technology graduates, surely requires a critical evalution of whether skills are being fully and rightly employed, as well as a tabulation of the subjective impressions of employers and inexperienced young graduates. This is certainly a much more difficult study but it is one that needs to be made.

I.B.

BCE 3029 for further information

CHAPMAN & HALL

★ *New British & American Books* ★

DISINFECTANTS

Their Values and Uses

by

W. E. Finch

Disinfectants Division
The Prince Regent Laboratories, London

Foreword by

H. Berry

B.Sc., F.P.S., F.R.I.C., Dip. Bact.
Professor Emeritus of Pharmaceutics,
University of London

188 pages *Illustrated* *30s. net.*

Many of the recent developments in the manufacture and use of disinfectants and antiseptics have been covered by papers published in scientific journals, but little effort has been made to deal with the subject as a whole. This work based on many years of practical experience in manufacturing laboratories, presents a balanced survey of all types of disinfectants and shows the uses and limitations of the various groups.

★ ★ ★

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BCE 3030 for further information

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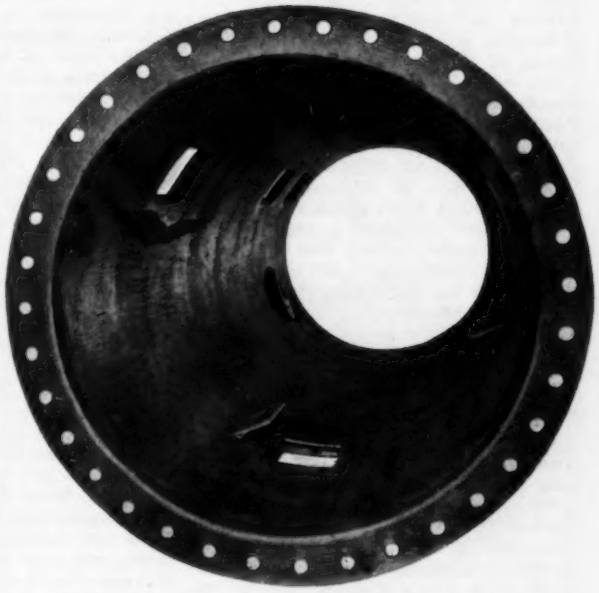

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PLANT EQUIPMENT NEWS

Tester for Plant Tubes

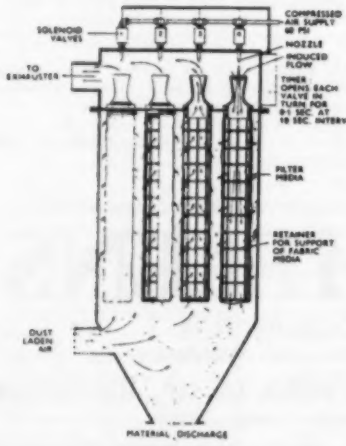
The Introview flaw and corrosion detector has been designed specifically for the non-destructive testing of metal tubes of low magnetic permeability installed in condensers and heat exchangers, to permit an accurate assessment of their condition. The essential part of the instrument consists of a probe and recording unit, the probe normally working at a speed through the tube of 120 fpm. The recording unit produces on a moving chart a record of the local condition of the material under test, chart and winch speeds being interrelated. The instrument is being manufactured under licence from Imperial Chemical Industries Ltd. by **Sperry Gyroscope Co. Ltd., Great West Road, Brentford, Middlesex.**

BCE 3088 for further information

Dust Collector

The main advantage claimed for the new Mikro-Pulsaire dust collector, an American machine which is now being manufactured under licence by Pulverizing Machinery, is the absence of internal moving parts. The dust-carrying air passes into cylindrical filter elements composed of woollen and synthetic felts, 4 ft-6 ft long, and the separated dust falls from their external surfaces to be collected at the bottom of the pressure cabinet. Periodical high-pressure air currents in the reverse direction to the filter flow clear the cloths. Above the opening in the head of each cylinder is a nozzle connected to a compressed-air supply of 60 psi through a solenoid control valve. An electrical timer opens each valve in sequence for the period and frequency desired — for instance, 0.1-10 seconds. A flow of sufficient volume and pressure is induced to clear the filter cloths against the filter flow pressure.

The makers report that, in a field test on ground gypsum dust, the filter ran for nearly 3000 hours without failure and in over five months it received no maintenance, although working 24 hours a day six days a week. Another unit filtering copper powder has been in operation for over 2000 hours without failure. Abrasive and toxic dusts are said to present no particular difficulty. The manufacturers are trying to develop a filter medium which will withstand temperatures of about 1000°C, and they plan to develop a pneumatic timing device to control the duration of the reverse air jet.



The filter is made in three models covering the capacities 640-5000 cfm. Requirements of air at 60 psi are 1-2 cfm for the smallest and 6-8 cfm for the largest model. The machines are compact. **Pulverizing Machinery Ltd., Fishponds, Bristol.**

BCE 3089 for further information

New Process Timer

Rodene's type 7000 auto-reset timer is a clock-faced flush-mounting instrument that can be controlled by a switch or push buttons and can be connected to reset automatically at the end of the timed period or when a resetting contact is opened. Seven time scales are available, ranging from 0-15 seconds to 0-3 hours, and others are planned. During timing, one hand, coloured red, remains stationary to mark the set time, while a black hand travels back to zero to indicate the unelapsed time. The instrument can be supplied with the control knob on a removable shaft. **Rodene Electrical Co. Ltd., 579 London Road, Isleworth, Middlesex.**

BCE 3090 for furtherinformation

Electro-hydraulic Valve Actuators

Now in production at the Rochester works of Fisher Governor are two new electro-hydraulic valve operators, types 340 and 350. Self-contained, they have been designed to be of special use in electrical control loops. They incorporate a hydraulic pilot which is operated by a simple force motor and which uses nozzle-flapper combinations to control hydraulic pressure. Two sizes are available, each adaptable to all DC output signals. The type 340 has a maximum stem thrust of 600 lb. and is suitable for valve sizes ¼-4 in. Type 350 develops a thrust of 2000 lb. and is usable for all valve sizes up to 16 in. **Fisher Governor Co. Ltd., Airport Works, Maidstone Road, Rochester, Kent.**

BCE 3091 for further information

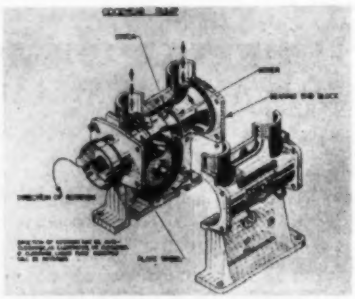
Smoke Density Indicator

The Shandon Glowring smoke density indicator, which has been developed by the Fuel Research Station of the D.S.I.R., consists of a special glowing element (the Glowring) placed in the side flue. The element is viewed through a column of flue gas from an observation window in the front wall of the flue. The brightness of the Glowring can be adjusted, so that it is obscured when the smoke density corresponds with No. 2 shade on the Ringelmann chart. The only surface to be cleaned is the observation window, which is easily accessible. Any deposit on the glowing element is burnt off. **Shandon Scientific Co. Ltd., 6 Cromwell Place, London, S.W.7.**

BCE 3092 for further information

Versatile Screw Pump

The new continuous, self-priming, self-lubricating pump by Goodyear Pumps of Cornwall is described as a positive axial-flow unit employing a screw (rotor) of new form. This screw engages with a rotating plate to produce, it is said, a positive pulseless action. The rotor and plate wheel are the only moving parts, and since the rotor spins on its own true centres there is no tendency to roll and rub against the surrounding rubber stator. Symmetry of design enables the rotor to turn in either direction. All



engaging surfaces are rubber-to-metal, fluid lubricated, and a relief valve is supplied where shut-down valves are incorporated on the delivery side. The makers state that the pump can tackle air and liquid in any proportion and can run continuously "on snore", while its simple positive action and low fluid velocity enable it to deal with thick and viscous fluids with ease. The present range of three sizes covers the capacities of from 2½ to 224 gallons a minute. **Goodyear Pumps Ltd., Camborne.**

BCE 3093 for further information

Hydraulic Thermostat

The Compenstat by Gallenkamp, a new hydraulic thermostat, has been designed for accurate temperature control, together with automatic compensation for changes in ambient temperature. The device consists of a sensing bulb connected by a capillary tube to bellows in the control head. These operate a snap-action micro-switch in the heater circuit. Extra sensitivity is achieved by a small auxiliary heater wound around the capillary tube, which shortens the cycle of operation and limits temperature fluctuation and overshoot. Automatic compensation for changes in control-head temperature is

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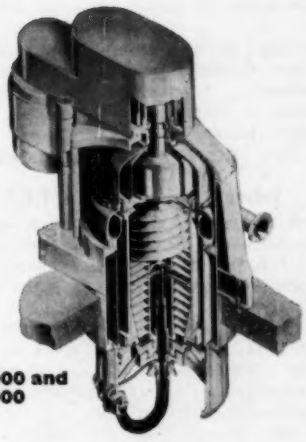

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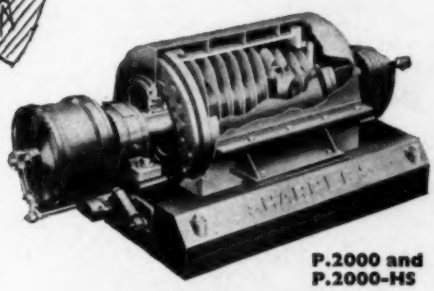
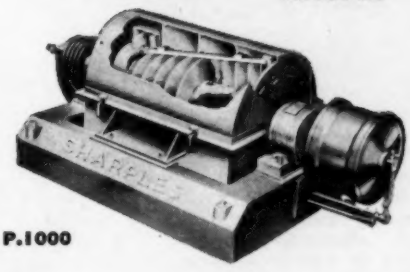


P.2000 and P.2000-HS



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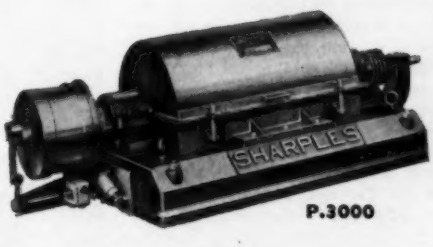

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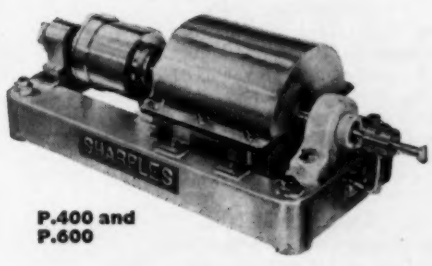

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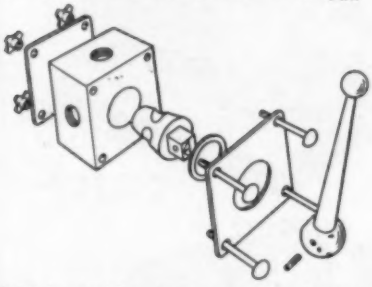
PLANT EQUIPMENT NEWS

achieved by a separate bellows system. The instruments are incorporated in the company's new range of laboratory ovens. **A. Gallenkamp & Co. Ltd., Sun Street, London, E.C.2.**

BCE 3094 for further information

Valves and Fittings in P.T.F.E.

A new series of fluid control valves, pipework and fittings made from solid P.T.F.E. is being made available by Watson-Marlow. Each of the three types of valve in this "Omega" range has been designed to control combinations of direction, volume and pressure in the flow of any fluid, acid, alkali or solvent (except fluorine and molten alkali metals). There is only one moving part in each and one material only in the path of the fluid. The makers state that body and plug are accurately machined from solid, first-grade P.T.F.E. (Fluon or polytetrafluoroethylene). They are



held in position by two rigid clamping plates, tightened by four screws, and there is an ample anti-friction ring, also in P.T.F.E., between the front plate and the shoulder of the plug. No lubricant or sealing compound is required. The operating temperature range of the valves' constructional material is from −50°F to +450°F and steam and autoclave sterilisation temperatures cause no problem it is claimed. The Omega 4.5 provides a continuously adjustable by-pass and a complete stop in the main line in one unit. The valve has been continuously and shock tested at up to 170 psi without sign of leakage. At this pressure the torque required to operate the handle was less than 3 ft/lb. **Watson-Marlow Air Pump Co., Marlow, Bucks.**

BCE 3095 for further information

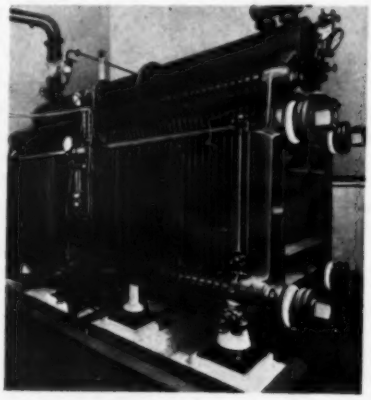
Collapsible Tanks

The top loading of the collapsible tanks made by Green and Silley Weir is 300 lb. per sq. ft and not as stated in BRITISH CHEMICAL ENGINEERING, March, 1958, p. 168. **R. & H. Green and Silley Weir Ltd., 18 London Street, London, E.C.3.**

BCE 3096 for further information

Electrolysis Plant

The largest single filter-press type of electrolyser so far designed and supplied from the United Kingdom was commissioned recently at the Reykjavik

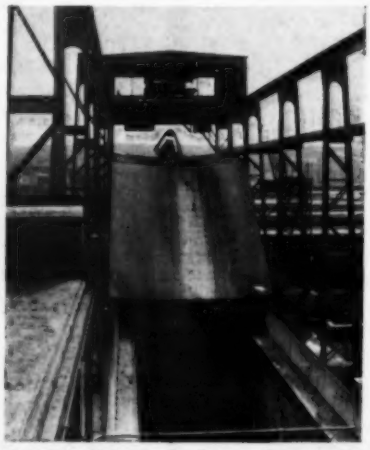


plant of Aburdarverksmidjan H.F. (The Fertiliser Plant Inc.) by Constructors John Brown. Delivering 10,000 cu. ft/hr of hydrogen at 99.95% purity and 5000 cu. ft/hr of oxygen at 99.7% purity, the electrolyser occupies a floor space of only 285 sq. ft. Direct current for the electrolysis is supplied by a motor-generator set working off a 6000 v. A.C. main. The hydrogen is used for ammonia synthesis. **Constructors John Brown Ltd., 73 South Audley Street, London, W.1.**

BCE 3097 for further information

Electronic Ratemeter

The latest addition to the range of Londex instruments is a continuously indicating electronic ratemeter which provides a range of indication of from 1 to 20 counts per second in ¼ divisions, with



This scale chute at the Brinsworth continuous, medium-width strip mill of Steel, Peech & Tozer, Rotherham, covers an area of 3000 sq. ft and was coated in September 1957 with United Coke & Chemical's Ulak No. 4 primer and epoxide paint. Originally, the chute was coated with red lead paint, most of which had disappeared, leaving part bare metal and part corroded metal surfaces. Loyne Ltd., of Ashton-under-Lyne, who did the painting, would not normally attempt to coat such a surface with epoxide paint without prior shot-blasting treatment, but the use of Ulak No. 4 made it a practical proposition and also reduced the cost. Six months later, the coating was still in excellent condition and no "lifting" of either the primer or epoxide had occurred.

an accuracy to ¼ article per second. The indicating instrument response time to sudden changes of 5 per second is less than 2½ seconds. The instrument may be used wherever electrical impulses can be derived from a suitable transducer, and can be applied not only to, for example, monitoring rates of production, but to the automatic regulation of a production process by feeding back an appropriate signal to a regulating control. **Londex Ltd., 207 Anerley Road, London, S.E.20.**

BCE 3098 for further information

Other Items

To meet the demand for a more compact and inexpensive air filter unit, Visco Engineering have now developed the "M.V." type dry air filter. It occupies only about two-thirds the space required for their "C.E." filter of equal capacity, and the makers say it is more economical to install and maintain. **The Visco Engineering Co. Ltd., Stafford Road, Croydon.**

BCE 3099 for further information

Formica are making available their GE.10 glass-fibre epoxy resin laminate in sizes up to 38 in by 28 in. **Formica Ltd., 84 Regent Street, London, W.1.**

BCE 3100 for further information

By modifying an F. & J. light duty conveyor by fitting special rubber seals along the length of the belt on each side and by providing a special chute and hopper at the delivery end, the machine has been adapted to the conveying of small quantities of demerara sugar. The special chute was designed to accept any surplus sugar left adhering to the belt after passing the filling machine hopper orifice. **British Automatic Conveyor & Equipment Co. Ltd. (Division of Farrow & Jackson Ltd.), 41 Prescot Street, London, E.1.**

BCE 3101 for further information

Seen at the O.C.C.A. Exhibition

Novel Heating Equipment

A novel resistance and inductive method of low-voltage heating for process industries, for which many advantages are claimed, was shown by Kestner. The design includes the use of the wall of the vessel to be heated as part of the secondary winding of a high-efficiency transformer. That winding is designed as a single sheet turn for most of its construction and its use eliminates end effect and transmission cable losses. The system is applicable to pipes or vessels of diameter from ¾ in. to 12 in. The secondary circuit encloses much of the lagging of the vessel, which both reduces heat losses and prevents the primary windings from heating more than necessary. The final lagging is enclosed in an outer casing which can be flameproofed. Claims for the design include an efficiency of 90% and a power factor of greater than 0.9. The equipment is robust, simple to make, and needs no heat-transfer medium. The "Isoductive" equipment, as it is known,

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PLANT EQUIPMENT NEWS

lends itself to easy and accurate control of temperature. At present the equipment is being recommended for the heating of reaction and distillation vessels and pipelines and for booster heaters and preheaters.

Kestners have also made available a furnace designed to produce outlet gases at an accurately controlled temperature. Adaptable for gas or oil fuel, it is the essential part of their patent heat-coil immersion heating system, which is of special use in the heat treatment of thermo-labile substances. The principle of the equipment is that additional air is fed as required to a high-efficiency furnace to obtain the desired temperature in the outlet gases. The additional air cools the furnace walls before being mixed with the hot gases, thus minimising heat losses from the furnace. The exhaust gases at a high velocity are then fed to a multi-turn immersion coil, the system being adjusted so that the gases leave the coil at a temperature little above that of the charge being heated. The ability of the furnace to function at "any reasonable distance" from the vessel to be heated is useful where flameproof processing is necessary. It also enables more than one set of equipment to be operated from a single furnace. For cooling, the immersion coil may also be fed with cold air at high speed. **Kestner Evaporator & Engineering Co. Ltd., 5 Grosvenor Gardens, London, S.W.1.**

BCE 3102 for further information

Impeller Mixers

The new Super Rapid mixers by Steele & Cowlishaw have been designed for processing materials in containers of from 50 to 250 gallons capacity. The impeller, fitted to a vertical shaft, rotates at any predetermined speed from 150 to 2000 rpm. Also being made available

by the company is a new cone blender for solids which has an offset axis and which produces a swirling effect resulting, it is claimed, in efficient mixing without the need for centre baffles. **Steele & Cowlishaw Ltd., Cooper Street, Hanley, Stoke-on-Trent.**

BCE 3103 for further information

Vibratory Mixer

A vibratory mixer said to be of completely new design is being made by Q.V.F. Its energising unit is a vibration generator which operates from an alternating current and vibrates a stainless-steel shaft and plate immersed in the liquid to be mixed in short powerful vertical strokes. The mixing action can be increased or decreased by altering the stroke length. Three models are available to cover the capacity range 10-3000 litres. **Q.V.F. Ltd., Duke Street, Fenton, Stoke-on-Trent.**

BCE 3104 for further information

Condensation System for Resin Plant

Metal Propellers Ltd., announced at the exhibition that, to obviate the difficulties experienced in alkyd resin production through the deposition of phthalic anhydride and phthalic acid as carry-over from the main reaction vessel into the condensation system, they have designed a new integral condensation system for which a patent application has been made. The protection covers the mounting of a separator pot directly above the vessel lid, the pot serving for upward travel of vapour, and separation of the solvent-water mixture. On the top of the separator is mounted a tubular reflux condenser. The following advantages are claimed for the device: (1) All surfaces of the unit where deposition could take place are continuously washed by solvent. (2) Solvent overflows back into the still at a temperature close to its boiling point. (3) Solvent and phthalic are scrubbed in the water layer, any phthalic acid formed being dissolved in the water. (4) When the plant is shut down, phthalic anhydride and acid remain in the water or the solvent layer. (5) The separator and condenser are taken on the lid of the still, and external liquid and vapour lines are eliminated. (6) The unit can be used when the plant is operating with the fusion process. **Metal Propellers Ltd., 74 Purley Way, Croydon, Surrey.**

BCE 3105 for further information

Paint and Ink Plant

A new automatic plant for paint and printing ink manufacture, shown by Torrance, consists essentially of a container which holds a quantity of high-density (steatite) beads, the main instrument of dispersion, which are agitated by a disc impeller. The product to be processed is introduced and extracted through stout slotted inlets and outlets which stand up indefinitely, the makers say, to continuous processing. The con-

trol panel is provided with interlocks which, among other functions, control input and output pumps, and are so arranged that it is impossible for the extraction pump to run whilst the input pump is running. It is possible to adjust the delay between the times when the input pump stops and the extraction pumps starts up, and this adjustment, in effect, is the method of controlling the quality of dispersion. Among the safety precautions built into the plant is the provision for a thermostat to trip the main switch when a predetermined danger limit in temperature is reached. The plant, Torrance point out, is designed to operate automatically for 24 hours a day. A laboratory batch unit is also supplied for pilot work. **Torrance & Sons Ltd., Bitton, Near Bristol.**

BCE 3106 for further information

Modified Cage Mixer

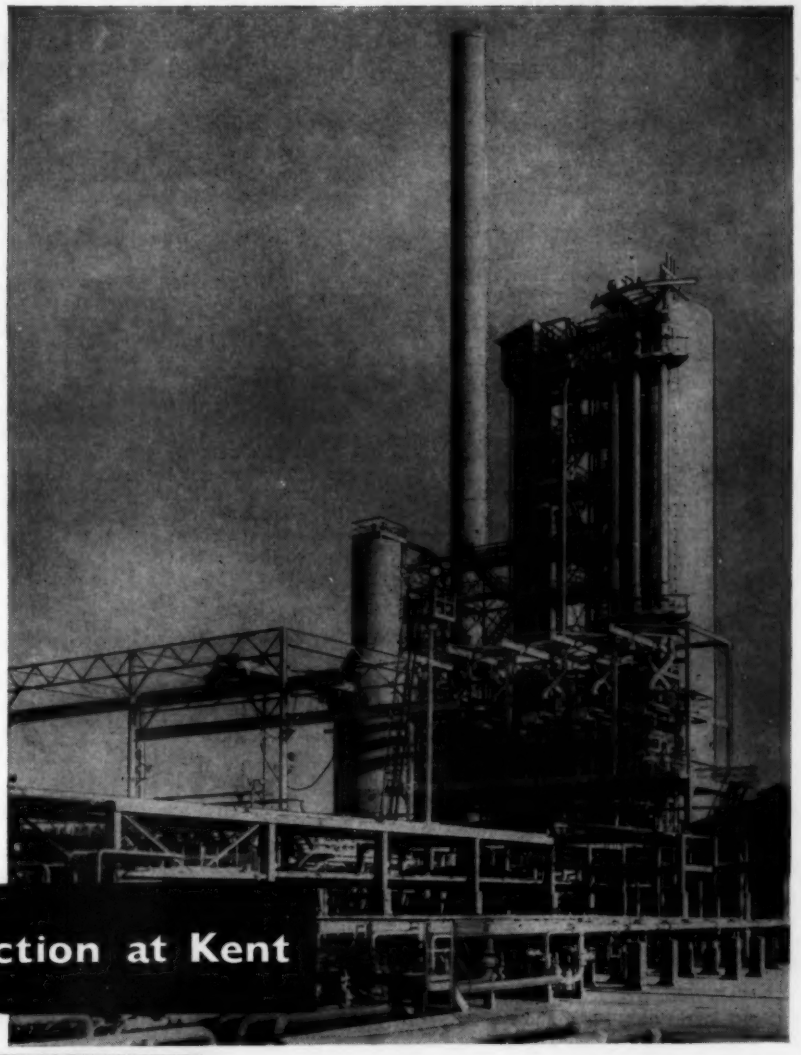
Modifications recently introduced to the Ultramix immersion high-speed mixing machine by Vickers Armstrong include serrations to the top and bottom plates of the "cage" and the addition of wings to the rotor. They are designed to produce a shearing effect in parallel with the direction of rotation. **Vickers-Armstrong (Engineers) Ltd., Vickers House, Broadway, London, S.W.1.**

BCE 3107 for further information

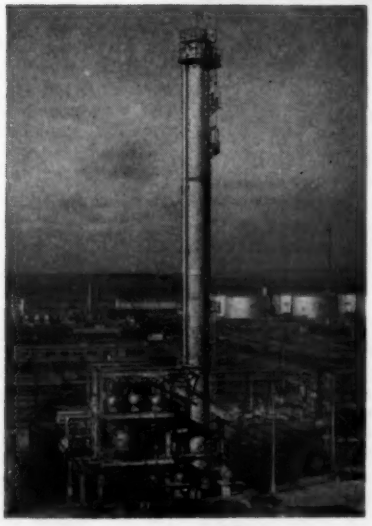
Induction Heating Plant

A 10-gallon induction heating plant being made available by L. A. Mitchell in conjunction with Metropolitan Vickers Ltd. has been specially designed for esterification and polymerisation reactions, and it can be arranged to suit a wide variety of processes where chemical reactions need to be controlled between fine limits. The standard plant can be fitted readily with interchangeable reactors of from 5 to 25 gallons capacity. The reactor is held on a hydraulic ram, operated from a cotnrol panel, and it is opened by releasing quick-release nuts on the kettle head. The installation is automatic and, the company say, will maintain any pre-set temperature between 0°C and 400°C to within ±1°C.

This 80,000 BPSD Distillation Unit designed by Badger has recently gone on stream at the Kent Refinery of The British Petroleum Company.



Construction at Kent



A number of other Badger designed process units are currently under construction at the same location. The many skills required for the design and construction of these units are available to all our clients. Let us tell you how we may be of assistance to you.

E. B. BADGER & SONS LIMITED
20 RED LION STREET, LONDON, W.C.1
Telephone: CHANCERY 3366 TELEX No. 2-3512
Affiliated with STONE & WEBSTER ENGINEERING CORPORATION, U.S.A.

PLANT EQUIPMENT NEWS

The reactor can be fitted with a fixed or multi-speed stirrer, and a vacuum of 29.5 in. Hg can be maintained in it. The reactor, condenser and receiver are constructed in FDP stainless steel, but other steels can be used if required. **L. A. Mitchell Ltd., 37 Peter Street, Manchester, 2.**

BCE 3108 for further information

5-hp Mill

The Premier mark II 3-in. mill is now being fitted with modified water-cooling system and a more powerful motor (5 hp instead of 2½ hp). **Premier Colloid Mills Ltd., Hersham Trading Estate, Walton-on-Thames.**

BCE 3109 for further information

New Coatings

Epikote resin coal-tar formulations for the lining of pipes and tanks and for the protection of chemical plant were illustrated by **Shell Chemical Co. Ltd., 15 Great Marlborough Street, London, W.1.**

BCE 3110 for further information

Mica and organic titanium compounds for use as ingredients of corrosion-prevention paints were exhibited by respectively **Micafine Ltd., Raynesway, Derby,** and **Laporte Titanium Ltd., 14 Hanover Square, London, W.1.**

BCE 3111 for further information

Materials to produce a rigid foam by the reaction of an alkyd resin and a polyisocyanate were shown by I.C.I. The foam, which can be made *in situ*, not only acts as a heat insulator but also protects the treated surfaces. **Imperial Chemical Industries Ltd., Imperial Chemical House, Millbank, London, S.W.1.**

BCE 3112 for further information

New Materials

Newly-introduced silicone products include the first of a range of silicone resins EP.65 and EP.66 by I.C.I. which are designed to meet the requirements of manufacturing silicone resin bonded glass-cloth laminates. A new development product from the same house is silicone resin DP.76, a dipping and impregnating varnish which, it is said, has good thermal stability and resistance to crazing at temperatures down to −55°C. Silicone resins DP.37 and DP.38 are intended for inclusion in protective and other coatings and are said to provide resistance to heat, weathering and chemicals. Silicone Elastomer E.394 is a putty-like paste designed for coating glass or fabrics used in high- or low-temperature electrical and mechanical applications. **Imperial Chemical Industries Ltd., Silicones Department, Stevenston, Ayrshire.**

BCE 3113 for further information

Physical Instruments on Exhibition

Developments in computers were a notable feature of this year's Physical Society's exhibition. Among this new equipment was the Emiac II analogue computer by E.M.I. ELECTRONICS LTD., Hayes, Middlesex. Designed to be compact and simple in operation so the users need no specialised electronic knowledge, it embodies a system of time division or mark space ratio multipliers which, E.M.I. state, has been developed to a point where it compares favourably in accuracy with servo-driven potentiometer multipliers, yet it has none of the disadvantages of a mechanical servo. The machine solves simultaneous differential equations, linear and non-linear, having time as the independent variable. Problems can be handled in real time, with an actual piece of the device under study linked into circuit, or scaled so that a cycle can be speeded 100 to 1000 times. For adaptability, the various computing units are interchangeable in a standard module accommodating 18 units. In the rare event of a fault a new unit can be inserted without disturbing the computing components.

BCE 3114 for further information

The ROYAL AIRCRAFT ESTABLISHMENT, Farnborough, demonstrated a simple model of a digital differential an lyser (D.D.A.) to show the principles of what they say will eventually be a large, fast computer. The basic component of a D.D.A. is a device which performs approximate integration by finite differences, and, as far as the user is concerned, appears similar to the wheel-and-disc integrator of a mechanical differential analyser. The Establishment is developing an electronic model which will, it is claimed, compare well in in capacity with proprietary electronic analogue differential analysers now in use, and will be much more accurate, and will allow precise repetition of

E.M.I.'s Emiac II.

results. A new optical digitiser was shown by HILGER & WATTS LTD., 98 St. Pancras Way, London, N.W.1.

BCE 3115 for further information

No. 402 F, the latest model in the series of digital computers by ELLIOTT BROTHERS (LONDON) LTD., Elstree Way, Borehamwood, Herts., can work under programme control in either floating point or fixed point modes. It consists of a 402E (fixed point) computer with three extra cabinets. It was demonstrated in four typical applications: (1) solution of n simultaneous equations $ax = b$ with m right-hand sides, using minimum storage space; (2) a linear programming problem; (3) multiple regression analysis; and (4) simple autocode programming. SOLARTRON ELECTRONIC GROUP LTD., Thames Ditton, Surrey, showed their precision analogue computing units which can be built up to make analogue computers of any size.

BCE 3116 for further information

Developments made public on other stands include the announcement by PHILIPS ELECTRICAL LTD., Shaftesbury Avenue, London, W.C.2. that their gas refrigeration machine PW 7000 (see BRITISH CHEMICAL ENGINEERING, 1957, December, p. 690) is to be equipped with a separating column which, at atmosphere pressure, will separate liquid nitrogen and oxygen from the liquid air which it initially forms when supplied with gaseous air.

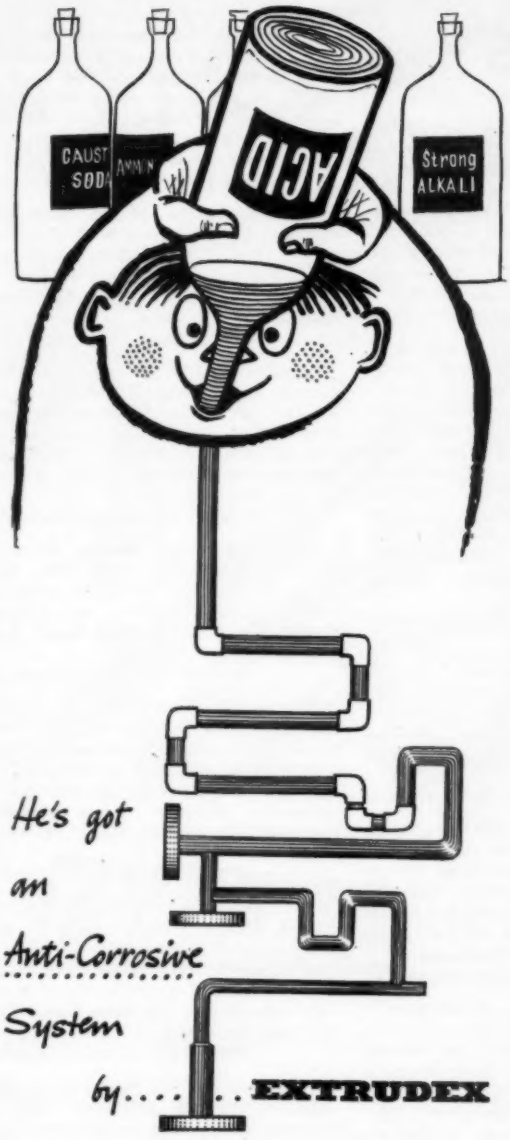
BCE 3117 for further information

A development model of silicon carbide-graphite thermocouple shown by MORGAN CRUCIBLE CO. LTD., 52 Battersea Park Road, London, S.W.11, uses a low resistance silicon carbide as one member of the couple and as a protecting outer sheath. The standard thermocouple consists of the silicon carbide outer tube 10 mm. o/d in lengths up to 500 mm. containing a central graphite rod. The graphite is joined to the tube by a conducting silicon carbide cement, which also acts as a protective coating. Care has been taken to minimise oxidation of the graphite rod. For additional protection and insulation an alumina coating can be provided.

BCE 3118 for further information

The zone-melting apparatus shown by BAIRD & TATLOCK (LONDON) LTD., 14 St. Cross Street, London, E.C.1, which has been developed from the Chemical Research Laboratory apparatus, is a tower with clamp and supports for a vertical melting tube, 3 ft by 1½ in., down which a heater, in the form of a narrow ring surrounding the tube, travels at about 1.3 in. per hour. The material for purification is melted, poured into the tube and allowed to solidify. The heater is set to give a molten zone with a temperature of 2° to 3°C above the melting point of the substance being purified and the zone is 1-3 in. long,

BCE 3034 for further information



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BCE 3035 for further information

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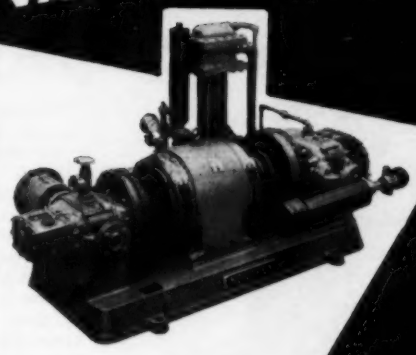

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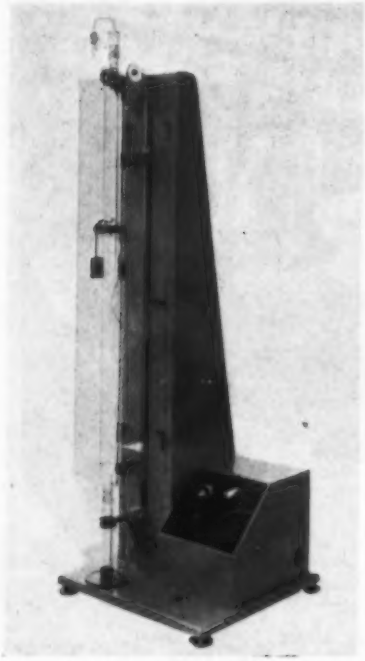
PLANT EQUIPMENT NEWS



B.T.L.'s Zone Melting Apparatus.

depending on the thermal properties of the substance, and travels down the tube with the heater. When the heater reaches a micro-switch a solenoid-operated clutch engages the rewind motor, which returns the heater quickly to an upper micro-switch, completing one cycle.

BCE 3119 for further information

Three experimental models of high resolution nuclear magnetic resonance spectrometers were on show—exhibited by MULLARD RESEARCH LABORATORIES, Cross Oak Lane, Salfords, Near Redhill, Surrey; THE GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, W.C.2; and METROPOLITAN-VICKERS ELECTRICAL CO. LTD., Trafford Park, Manchester, 17. A method for nickel plating by the thermal decomposition of nickel carbonyl *in vacuo* was demonstrated by the ATOMIC WEAPONS RESEARCH ESTABLISHMENT, Aldermaston, Berks.

BCE 3120 for further information

Mullard's Spectrometer.

New Publications

A recent leaflet (No. 296) explaining the basic principles of their spray drying plant and listing the products successfully dealt with by this type of plant has been issued by **Kestner-Evaporator & Engineering Co. Ltd., 5 Grosvenor Gardens, Westminster, London, S.W.1.**

BCE 3121 for further information

Publication No. 328 by Evershed & Vignoles covers three auxiliary equipments designed to extend the applications of this company's Dionic water purity meter. The equipments are, namely, a water cooler, a steam condenser and a Straub degassing condenser. The working principles of the auxiliaries are described, and photographic illustrations and sectional diagrams are included. **Evershed & Vignoles Ltd., Acton Lane Works, Chiswick, London, W.4.**

BCE 3122 for further information

The recently published Drayton/Armstrong steam trap manual contains sections on the working of traps, capacity charts, testing, maintenance and trouble shooting. Copies from **The Drayton Regulator & Instrument Co. Ltd., West Drayton, Middlesex.**

BCE 3123 for further information

A manual on anti-corrosion practice is always worthy of attention and chemical engineers will be interested to see a copy of such a manual entitled "Dunclad Chemical Plant Linings" published by the **Dunlop Rubber Co. Ltd., G.R.G. Division, Cambridge Street, Manchester.**

BCE 3124 for further information

Continuing their policy of issuing technical information about the properties, design, finishing and use of die-castings, Fry's Diecastings Ltd. have recently brought out a new publication entitled "Aluminium Alloy Pressure Die-castings". Copies from the company's **Midland Works, Brierley Hill Road, Wordsley, Nr. Stourbridge.**

BCE 3125 for further information

A new technical brochure giving details of their range of airfoil centrifugal fans has been issued by **The Midland Heating & Ventilating Co. Ltd., Bedford Road, Birmingham, 11.**

BCE 3126 for further information

Publication No. 69, by W. C. Holmes, is a new issue which deals with the subject of [Electroprecipitation] in a most thorough manner. Starting with a general introduction to the subject, the publication follows on with principles, practical aspects, equipment and applications. Title of the publication is "Electrical Precipitators". **W. C. Holmes & Co. Ltd., Gas Cleaning Division, P.O. Box B7, Tunbridge, Huddersfield.**

BCE 3127 for further information

The design and performance of a small multi-tray oven for the low-temperature heating of solids which was elaborated by the Industrial Gas Development Committee of the Gas Council is contained in the Council's Report No. 646/57. Full details of the oven are possessed by Stewart Gill & Co. Ltd., Hayes, Middlesex. **The Gas Council, 1 Grosvenor Place, London, S.W.1.**

BCE 3128 for further information

The dehydration of air gases and liquids with Humidryers is illustrated in the recently published brochure, "Dehydration", issued by **Burnett & Lewis Ltd., Redhouse Industrial Estate, Aldridge, Staffs.**

BCE 3129 for further information

A leaflet describing a resistance-heated vacuum furnace (model 2904) which can be used for melting, alloying, pouring, heat-treating, sintering and annealing has been published by **Wild-Barfield Electric Furnaces Ltd., Otterspool Way, Watford By-pass, Watford, Herts.**

BCE 3130 for further information

The latest booklet to be issued by Clayton Engineering deals with their indicators for the precision setting of rotary controls, valves, etc. **Clayton Engineering Co., Cannhall Road, London, E.11.**

BCE 3131 for further information

"Pneumatic Handing" is the title of a 23-page booklet in colour devoted to the handling of materials carried by barge and ship and conveyed at coaling plants and in other industrial installations by pneumatic methods. **Simon Handling Engineers Ltd., Cheadle Heath, Stockport, Cheshire.**

BCE 3132 for further information

Incandescent Heat have published two leaflets dealing with, respectively, their tile-suspended arch designed for high-temperature furnaces where thick insulation is required, and their interchangeable furnace arch. **The Incandescent Heat Co. Ltd., Smethwick.**

BCE 3133 for further information

Catalogue No. 690 published by Dewrance covers the company's range of pressure gauges and needle valves and other equipment. **Dewrance & Co. Ltd., Great Dover Street, London, S.E.1.**

BCE 3134 for further information

Some of the newest chemical plant available and tested in titanium is illustrated in I.C.I.'s pamphlet, "Titanium for Chemical Plant". **Imperial Chemical Industries Ltd., Metals Division, P.O. Box 216, Birmingham, 6.**

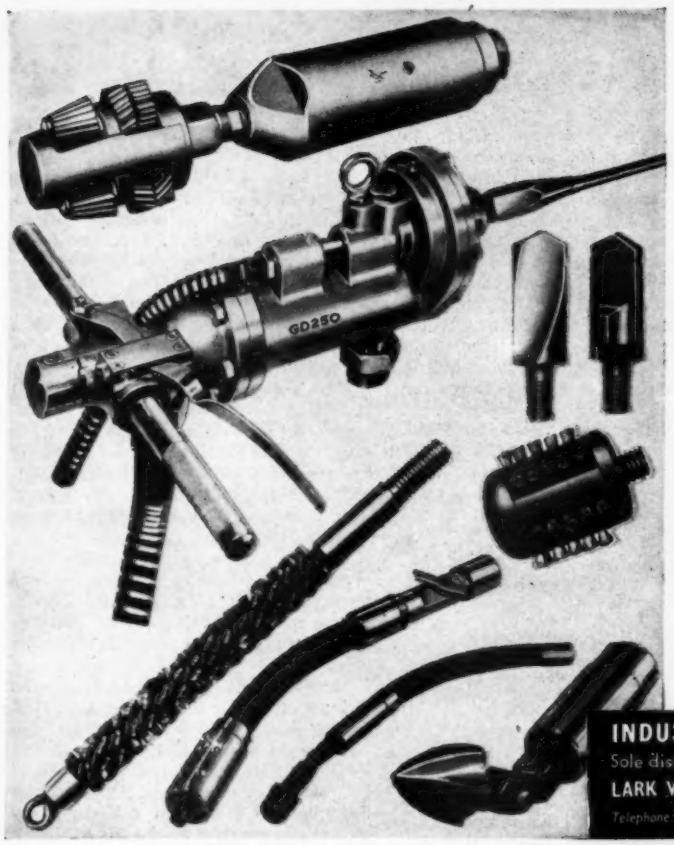
BCE 3135 for further information

A description of Griffiths' standard range of unit industrial dust collectors, with mention of modifications for use with inflammable and explosive materials, is contained in their brochure D/1. **A. E. Griffiths (Smethwick) Ltd., Booth Street, Birmingham, 21.**

BCE 3136 for further information

Technical Publication 1631 contains details of the Model 63 series of constant differential relay flow controllers manufactured by **Sunvic Controls Ltd., P.O. Box 1, Harlow, Essex.**

BCE 3137 for further information



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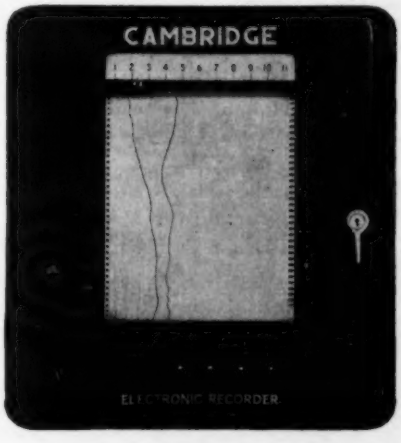
Cambridge

Industrial pH and Conductivity



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Month's News in Brief

New Company

Yorkshire Imperial Metals Ltd., the new company formed jointly by I.C.I. and the Yorkshire Copper Works Ltd., is now in being, with assets worth about £18,000,000. Dr. J. Taylor, I.C.I. director responsible for Metals and Nobel Division, has been named as chairman.

New Division

Woodall-Duckham Construction Co. Ltd. announce that, to meet the changing needs of the gas, oil and chemical industries, a high-pressure processes division has been established with Mr. H. S. Cheetham as director in charge. The new division will concentrate upon the provision of complete plants for the production of gases suitable for town supply and chemical synthesis, etc., using modern high-pressure techniques.

Proposed Conferences, Symposia, etc.

A two-week appreciation course on "The Design of Equipment for Human Use" will be of particular interest to companies manufacturing or using complex equipment, such as machine tools, control desks, instrument panels, etc., which have to be worked or controlled by human operators. Particulars of the course, which is the first of its kind to be held in this country and will be held from May 5 to 16, may be obtained from Engineering and Allied Employers' West of England Association, Engineers' House, The Promenade, Clifton Down, Bristol, 8.

A joint symposium on "Instrumentation and Computation in Process Development and Plant Design" will be held in the Central Hall, Westminster, on May 11, 12 and 13, 1959. This meeting is being organised by The Institution of Chemical Engineers, the Society of Instrument Technology and The British Computer Society, under the ægis of The British Conference on Automation and Computation. Any person wishing to present a paper at the symposium should send a summary not later than June 1, 1958, to: The General Secretary, The Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1.

A one-day conference on statistical sampling in industry, organised by the Birmingham Group of the Industrial Applications Section of the Royal Statistical Society, will be held at the Birmingham College of Technology on May 7, 1958. Details and application forms can be obtained from D. Goldberg, A.E.I. Lamp & Lighting Co. Ltd., Melton Road, Leicester.

March 17 last saw the inauguration of the Scottish Agricultural Industries' Leith fertiliser works by Sir Alexander Fleck, chairman of I.C.I. Our photograph shows Sir Alexander (third from right) preparatory to his inaugural tour. On his right are: Sir Alexander Glenn, Secretary to the Department of Agriculture, and Mr. H. U. Cunningham, former managing director of S.A.I. On his left is Mr. E. P. Hudson, S.A.I.'s present managing director.

H. McNeil

People in the News

Babcock & Wilcox Ltd. announce the appointment of **Mr. Hector McNeil** as managing director of the company. He succeeds **Sir Kenneth Hague**, who has expressed the wish to relinquish that position, which he held since January, 1945. Sir Kenneth will continue to devote his services fully to the company in his position as deputy chairman.

Mr. McNeil was appointed general manager of the company in London in 1947, becoming a director in 1950 and deputy managing director in 1953. He is also a director of Dewrance & Co. Ltd. and of the German, Spanish and Australian Babcock & Wilcox companies. Since 1953 he has been a Member of Council of the Institute of Fuel, was vice-president of that Institute from 1953 to 1956 and became president in 1957. Other changes announced by the company are: **Mr. J. Stewart Robertson**, general manager, has been appointed a director to fill the vacancy created by the retirement from the board of directors, at his own request, of **Mr. C. H. Sparks**, a director for the past 18 years. Mr. Sparks will continue in his present capacity as engineering consultant to the company.

Dr. W. H. Garrett, director of Monsanto Chemicals Ltd., has been elected president of the British Employers Confederation in succession to **Sir Colin Anderson**. Dr. Garrett is vice-chairman of the Association of British Chemical Manufacturers and a life vice-president of the Association of Chemical and Allied Employers. He is a member of the Grand Council of the Federation of British Industries; the Industrial Disputes Tribunal; the Chemical Engineering Committee of King's College, London; the appointments board of Liverpool University; and is also a director of Metal Industries Ltd.

Mr. J. R. Allan has been appointed joint managing director of Acme Ventilating Ltd. Mr. Allan is already a director of Acme Conveyors Ltd., and holds the post of general manager of the Acme Group of Companies. The appointment is also announced of **Mr. P. Lowe** as sales director of Acme Ventilating Ltd., in addition to his present post of sales director of Acme Conveyors Ltd.

Mr. George C. Tuvey has been appointed sales director of Zwicky Ltd.

Dr. M. A. T. Rogers was appointed research controller of Imperial Chemical Industries Ltd. with effect from April 1, 1958. He succeeds **Mr. R. M. Winter**, who is retiring from the company after 30 years' service.

Flexibox Ltd. announce that **Mr. E. C. Weston** has been appointed general manager of the company. **Mr. J. Babington Smith** has also joined Flexibox to take charge of the company's London office.

Mr. R. L. Paice, who had been sales director of Igranic Electric Co. Ltd., Bedford, since 1948, relinquished this position on March 1, 1958. **Mr. A. W. Page**, as sales manager, is now responsible for the Home and Export Sales Organisation. Mr Paice will carry out special assignments of the board.

Albright & Wilson Ltd. announce the appointment of **Dr. Forrest F. Musgrave** as personal assistant to **Mr. Sydney Barratt**, chairman of the Albright & Wilson Group of Companies. Dr. Musgrave was formerly managing director of Lubrizol Great Britain Ltd.

Mr. R. Edgeworth Johnstone has been awarded the degree of D.Sc. by the University of London for work in the field of applications of model theory to chemical engineering.

Mr. M. H. M. Arnold has been appointed the technical director of Bowmans Chemicals Ltd.

Mr. B. W. Dawkins has been elected chairman of Saxon Engineering Co. Ltd. and Bennis Mechanizations Ltd., both subsidiary companies of Bennis Combustion Ltd., of which Mr. Dawkins is joint managing director.

Southern Instruments Ltd. announce that **Mr. Philip Sellars** has joined their board of directors as vice-chairman. Mr. Sellars will be responsible for the overall co-ordination of expansion activities planned by the company.

Mr. L. W. English, technical manager, has been appointed a director of Auto-Klean Strainers Ltd.

OBITUARY

The death is announced of **Sir James Swinburne**, F.R.S., the plastics pioneer who celebrated his hundredth birthday on February 28 last. Sir James who, until 1948, was chairman of Bakelite Ltd., made a major contribution to the modern plastics industry with his original work on phenolic resins.